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**Automatic Vehicle Location and Paratransit Productivity**

Jennifer A. Hardin
Rosemary G. Mathias
Michael C. Pietrzyk

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Automatic Vehicle Location
and Paratransit Productivity

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September 1996
# Automatic Vehicle Location and Paratransit Productivity

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<td>In 1995, the Center for Urban Transportation Research at the University of South Florida in Tampa conducted a study designed to test whether automatic vehicle location (AVL) could be used to improve paratransit productivity. The research was based on a case study conducted at a paratransit provider in Miami. The study found that AVL technology could potentially benefit paratransit systems by providing better (and more accurate) information relating to productivity (e.g., measuring on-time performance, vehicle dwell time, passenger ride time) and real-time service monitoring (e.g., monitoring drivers, estimating arrival times, locating addresses, documenting passenger no-shows, and tracking system safety). A checklist for paratransit systems considering the implementation of AVL is included.</td>
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Special thanks to Exzun Hidalgo and Jorge Azor, as well as their staff at Zuni Transportation, Inc., in Miami, Florida, for their active participation and cooperation throughout this project. This research would not have been possible without their full cooperation. We also appreciate the cooperation of AirTouch Teletrac, vendor of the AVL technology used for this project.

Thanks also to the AVL Project Steering Committee, which provided review and comments throughout the study: Susana Amigo, Metro-Dade Transit Agency; Jorge Azor, Zuni Transportation, Inc.; Drew DeCandis, COMSIS Mobility Services, Inc.; Larry Harman, LJH Consulting; Jo Ann Hutchinson, Florida Commission for the Transportation Disadvantaged; Roy Lave, SYSTAN, Inc.; and Boyd Thompson, ARC Transit in Palatka, Florida. We are particularly grateful for Roy Lave’s on-going review and active interest in this project.

A final thanks to CUTR researchers Richard Stasiak and Chris Billingsley, who assisted with the data retrieval and analysis, and to Steven Polzin and Joel Volinski for their helpful reviews and comments.
EXECUTIVE SUMMARY

Under a grant from the National Urban Transit Institute (NUTI), the Center for Urban Transportation Research (CUTR) at the University of South Florida in Tampa conducted research examining the relationship between automatic vehicle location (AVL) technology and paratransit productivity. The CUTR research team included researchers with expertise in paratransit operations, planning, and intelligent transportation systems (ITS).

The purpose of this study was to assess whether AVL systems contribute to improved paratransit system productivity through more efficient and effective scheduling and dispatching, vehicle monitoring, and driver accountability.

This report presents the outcome of research that focused on the application of AVL at a paratransit system in Miami, Florida. First, the report defines the currently available AVL technologies and their general applicability to transit and paratransit. Second, the AVL test site is described in detail. Third, the data collection and analysis are depicted. Finally, the report portrays CUTR’s findings. A checklist is provided to help paratransit systems determine whether AVL will help them achieve the desired results.

AVL technology has just recently begun to be applied to the paratransit field. Implementing this type of technology may help to improve paratransit productivity through better scheduling and routing practices, reduced ride time, and enhanced real-time customer service. For this study, CUTR examined the application of AVL technology to paratransit by looking at how the technology might be used to improve system productivity. Three performance measures were chosen to represent system productivity:

- **On-time performance**: whether the vehicle arrives at the scheduled pick-up time and delivers the passenger at the scheduled drop-off time.

- **Vehicle dwell time**: the elapsed time from when the driver arrives to pick-up a passenger and leaves the pick-up location; as well as the elapsed time from when the driver arrives at the drop-off location and leaves after dropping-off the passenger.

- **Travel time**: the elapsed time from when the vehicle leaves the passenger’s pick-up location and arrives at the passenger’s drop-off location.

Ideally, to measure the effectiveness of any new technology, a comparison would be made between the system’s productivity prior to the introduction of the new technology and the productivity after introduction of the new technology. In the ideal world, all other aspects of the system would be held constant to allow for a perfect comparison (e.g., vehicles, drivers, weather, routes, etc.). However, in the real world, perfect comparisons rarely can be made.
CUTR was able to collect and analyze useful AVL data from the paratransit provider that suggests how AVL of technology might be helpful for improving paratransit productivity. However, completion of this task required a considerable amount of time and data manipulation. The amount of time and level of effort required for this data analysis is likely beyond the capabilities of most paratransit operators working in a dynamic environment. The data are, however, useful for after-the-fact analysis for research purposes.

Thus, our findings suggest that the particular AVL technology used in this application is not, in its present state, suitable for this type of application (the AVL technology used was originally installed as a theft-deterrent and not specifically designed for the use in this application). Nonetheless, CUTR found that this particular type of AVL technology does have a number of useful real-time applications to paratransit, which could contribute toward improved paratransit productivity. Specifically, this AVL technology may be used to:

- **Monitor drivers**: New and veteran drivers may be tracked and/or monitored to ensure that schedules are adhered to and drivers are where they are supposed to be.

- **Vehicle location and estimated time of arrival (ETA)**: This information allows the dispatchers to determine exactly where a vehicle is and how far it is from its destination.

- **Look-up addresses and identify closest vehicle**: The AVL software may be used to look-up the locations of unfamiliar addresses and to identify the closes vehicle to a requested pick-up location.

- **Document passenger no-shows**: The ability to document passenger no-shows is enhanced by being able to show that the paratransit vehicle was on-time and at the requested pick-up location of a passenger who is a no-show.

- **Monitor safety and security**: AVL technology can be used by paratransit operators to improve the safety and security of vehicles, drivers, and passengers. Automatic vehicle tracking also makes it possible to monitor accidents and vehicle breakdowns in real-time.

This research project afforded a great opportunity to examine the potential applications of one type of AVL technology to the paratransit field. Three major issues that were identified for other systems interested in implementing an AVL system: (1) determining whether there is a need for AVL, (2) selecting which AVL technology to acquire, and (3) implementing an AVL system. A checklist that corresponds to this discussion is included.

Paratransit companies introducing AVL technology into their operation should recognize that the implementation process probably will not be swift or easy. Just as personal computers have little value if the user does not understand the logic behind their use, so, too, will AVL systems have little functional value if their use and capabilities—as well as limitations—are not fully understood.
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STUDY OVERVIEW

Under a grant from the National Urban Transit Institute (NUTI), the Center for Urban Transportation Research (CUTR) at the University of South Florida in Tampa conducted research examining the relationship between automatic vehicle location (AVL) technology and paratransit productivity. The CUTR research team included researchers with expertise in paratransit operations, planning, and intelligent transportation systems (ITS).

The purpose of this study was to assess whether AVL systems contribute to improved paratransit system productivity through more efficient and effective scheduling and dispatching, vehicle monitoring, and driver accountability.

Drivers contribute a great deal to the success and quality of a paratransit program. Paratransit drivers are responsible for interpreting and following directions provided by schedulers and dispatchers. In addition, drivers often function with little or no direct supervision. Therefore, the overall productivity of a paratransit system is directly related to the ability of reservationists, schedulers, and dispatchers to convey accurate trip information and directions to drivers. Conversely, dispatchers and schedulers depend on feedback and self-reported information from drivers concerning where they are, what they are doing, who they are transporting, and other pertinent trip information.

This report presents the outcome of research that focused on the application of AVL at a paratransit system in Miami, Florida. First, the report defines the currently available AVL technologies and their general applicability to transit and paratransit. Second, the AVL test site is described in detail. Third, the data collection and analysis are depicted. Finally, the report portrays CUTR’s findings. A checklist is provided to help paratransit systems determine whether AVL will help them achieve the desired results.

\[1\] The term “paratransit” is used generally to mean shared-ride, door-to-door or curb-to-curb service, typically provided using vans or automobiles. In this case requests for service are made at least one day in advance.
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AVL TECHNOLOGIES

Automatic vehicle location systems are computer-based vehicle tracking systems. Although originally developed and used for military purposes, AVL technology has begun to be used to monitor the movement of vehicles in transit and paratransit fleets, trucking companies, and in the field of public safety (i.e., police cars and ambulances) (Casey 1996).

Transit and paratransit agencies use AVL systems to monitor the real-time location of each vehicle. Real-time location information can then be compared to the scheduled location. This information can be applied to scheduling and dispatching to improve system efficiency and productivity (Casey 1996). Vehicles may be rerouted or trips reassigned in real-time based on AVL data. The information also may be used to enhance planning and management decisions. Customer satisfaction may be improved with the application of AVL technology in transit and paratransit by providing accurate information on where a vehicle is located at a particular time so that more accurate estimates may be given regarding an estimated pick-up time.

Table 1 shows two major types of AVL technologies—satellite-based and ground-based—their respective coverage areas, and reported accuracies. Available information for specific vendors was included in the examples.

Satellite-based AVL

Satellite-based AVL systems use satellite signals to establish vehicle locations. Satellite signals received from three or more points are used to calculate the differences in the position of a vehicle relative to a fixed point. Users of this type of AVL system take advantage of 24 Department of Defense Global Positioning System (GPS) satellites (Turnbull 1993, Casey 1996). Satellite time is free. Small, low cost, multichannel receivers that are compatible with other AVL system components are now available.

GPS-based AVL systems are relatively accurate and offer great flexibility. Vehicles can be tracked anywhere. However, because the satellites are also used for military purposes, the U.S.
Table 1
AVL Technology Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Coverage Area</th>
<th>Reported Accuracy</th>
</tr>
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<tr>
<td><strong>Satellite-based AVL</strong></td>
<td></td>
<td></td>
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<tr>
<td>GPS</td>
<td>Global</td>
<td>Very Good:</td>
</tr>
<tr>
<td>• Auto-Trac</td>
<td></td>
<td>50 feet</td>
</tr>
<tr>
<td>• Highway Master</td>
<td></td>
<td>30 feet</td>
</tr>
<tr>
<td>• QualComm</td>
<td></td>
<td>500 feet</td>
</tr>
<tr>
<td>DGPS</td>
<td>Global</td>
<td>Excellent:</td>
</tr>
<tr>
<td>• DCI</td>
<td></td>
<td>3.3 feet</td>
</tr>
<tr>
<td>• Acu-Q-Point</td>
<td></td>
<td>3.3 feet</td>
</tr>
<tr>
<td><strong>Ground-based AVL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signpost</td>
<td>Predefined routes</td>
<td>Good</td>
</tr>
<tr>
<td>Dead-reckoning &amp; Map Matching</td>
<td>Local</td>
<td>Poor</td>
</tr>
<tr>
<td>LORAN-C</td>
<td>North America</td>
<td>Good</td>
</tr>
<tr>
<td>Ground-based Radio Navigation</td>
<td>Predefined metro areas</td>
<td>Good:</td>
</tr>
<tr>
<td>• AirTouch Teletrac</td>
<td></td>
<td>150 feet (50 feet in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Southeast Florida)</td>
</tr>
</tbody>
</table>

Source: Based on *Metro Magazine*, May/June 1994, p. 44, and AVL vendor information.

The military employs selective availability (SA) of the satellites, which reduces the accuracy of the GPS location data (CUTR 1994, Casey 1996). This problem is being overcome through the use of Differential Global Positioning System (DGPS) receivers, which improve the accuracy of vehicle positioning data.

**Ground-based AVL**

Proximity beacons (signposts), dead-reckoning, and trilateration are three technologies often used with ground-based, or terrestrial, AVL systems.

Proximity beacons, or signpost technologies, have been used in transit for some time. This type of technology features transmitting devices that are located on signposts or overhead wires at different points along a transit route. Each transmitting device emits a code that identifies its
specific location. Each time a bus equipped with a receiver passes a signpost, a message regarding that specific bus and its location is sent to the central control facility (Turnbull 1993). This technology is a relatively simple approach to AVL and can be implemented by transit agencies rather quickly. In addition, signpost AVL systems are usually lower in cost than other ground-based AVL technologies. One drawback to this type of AVL technology is that it is only able to monitor the location of vehicles at signposts along a predetermined route. Therefore, there is no way of knowing the status of a vehicle between signposts or off the route.

Dead-reckoning AVL systems compute the location of a vehicle relative to a central starting point with a known position. An internal compass and odometer located in each vehicle are used to determine the vehicle’s distance from the known starting point. Dead-reckoning systems are relatively inexpensive compared to other available AVL technologies; however, they frequently produce inaccurate location readings because of fluctuations in the earth’s magnetic field, which may interfere with vehicle compass readings. Also, dead-reckoning systems are only able to produce location reports relative to the known starting point.

Finally, trilateration techniques use radio frequency transmissions to compute the location of vehicles. Transmissions from three or more points are used to calculate the position of a vehicle relative to a fixed point. LORAN-C is an existing navigation network that is sometimes used with trilateration AVL systems. LORAN-C uses low-frequency waves to provide signal coverage. Location is determined by the reception of transmissions and the associated timing of each. This system is very susceptible to radio frequency and electromagnetic interference, and reception problems are often encountered in urban canyons (CUTR 1994, Casey 1996). Trilateration AVL systems are relatively inexpensive compared to other AVL technologies. However, as with LORAN-C, AVL systems based on trilateration experience signal interference from high-rise buildings or in mountainous areas. Interference may lead to inaccurate location readings or no location reading at all.

Recently, ground-based AVL technologies have emerged that use subscriber-based radio location systems. These systems do not require that users have a dedicated radio frequency for the vehicle location and transmission medium. Rather, vehicle paging and receiving capabilities are provided through the radio tuner in these systems and connected with a central computer and operations center. Although subscriber-based AVL systems are relatively inexpensive, a significant financial investment is required by the vendor to construct the needed infrastructure;
therefore, these systems are usually only available in large urban areas with a large market potential (CUTR 1994).

One vendor that provides this type of subscriber-based AVL system in the greater Miami area is AirTouch Teletrac, headquartered in Garden Grove, California. AirTouch Teletrac subscriber-based AVL technology serves as the focus of the research under discussion for the remainder of this report and its basic characteristics will be described in the next section.

AirTouch Teletrac AVL System

The AirTouch Teletrac AVL system is a subscriber-based radio navigation system that does not require a dedicated radio frequency. The system uses several technologies to determine a vehicle’s location including digital paging, digital mapping, spread spectrum transmission, LORAN-C location computation algorithms, and multi-processor distributed network control center (CUTR 1994). It should be noted that, at the time of this study AirTouch Teletrac was in the process of selling the assets of the business to Teletrac, Inc., which may have impacted its ability to respond as quickly to technological problems or issues as would have been desired.

System Overview

In 1995, AirTouch Teletrac provided AVL services in six U.S. metropolitan areas: greater Los Angeles, Chicago, Detroit, Dallas/Fort Worth, Houston, and the greater Miami area (CUTR 1994). Its services include stolen vehicle recovery and emergency roadside assistance for private vehicle owners, and computer-aided dispatching and fleet monitoring for commercial companies (CUTR 1994). At the time of this research, AirTouch Teletrac maintained a network of 31 receiving antennas throughout the Dade, Broward, and Palm Beach tri-county area. Each AVL-equipped vehicle broadcasts a radio-frequency signal to all nearby receiving antennas. The distance of the vehicle to the antennas can be measured by the time it takes for the signal to travel to the antennas. This system is capable of tracking vehicles anywhere in the local area. The company guarantees the accuracy of its AVL system to the nearest 150 feet; the accuracy of the south Florida system is within the nearest 50 feet because of the relatively flat terrain (CUTR 1994).
Vehicles are equipped with vehicle location units (VLUs), which are composed of a transponder that identifies each vehicle and an antenna (either interior "pancake" type or mounted exterior type) that transmits and receives radio-frequency communication signals in the 900 MHz band to AirTouch Teletrac's operation center in Fort Lauderdale. One drawback of the system is that it does have some difficulty transmitting through large obstructions, such as mountains, tunnels, parking garages, and urban canyons formed by large buildings that line many downtown city streets, although this has not been a significant problem.

### System Software & Hardware

Commercial customers of the system track their vehicles using a workstation running AirTouch Teletrac's Fleet Director™ software. Vehicle locations are sent to fleet operator work stations via modem, using a dedicated phone line. The software is capable of continuously displaying the location of all vehicles in the fleet on an electronic base map of the greater Miami area. An Etak™ digital map of the metropolitan area, which shows major and minor arteries, is included in the Fleet Director™ software. The map also includes a geofile that contains virtually all of the streets and addresses in the local coverage area.

This AVL system also offers commercial customers optional status message terminals to provide mobile data communications without using two-way radios. Two types of terminals are available: status message terminals and message display terminals.

- **Status message terminals** provide preprogrammed messages only. Preprogrammed messages refer to "code words" that customers use in place of a longer descriptive phrase. These code words are preprogrammed into the message terminals (e.g., a "Pick-up" button to record passenger pick-ups). Each time a button on the terminal is pressed, the unique message associated with that button is transmitted to the Fleet Director™ work station, along with the location of the vehicle at the time the button was pushed.

- **Message display terminals** provide the ability to receive full text messages on a display in the vehicle, or send and receive form messages in addition to preprogrammed messages. A form message is simply a preprogrammed message that has "fill in the blanks" for variable information. For example, a message display terminal could include a form message that states "Pick-up Passenger __" where the blank allows the driver to input each passenger's unique trip number. These messages can be sent from the vehicle to the Fleet Director™ work station, or from the work station to a vehicle. Finally, the message display terminals allow the transmission of full text messages from the work station.
station to vehicles. For example, dispatchers would have the ability to transmit messages alerting drivers about trip cancellations or traffic conditions, etc.

Location and status information for each vehicle is recorded and displayed in real-time, and is stored in a computer file to allow for vehicle history replays and report generation. The software allows users to replay the actual movement and status history for a single vehicle or all vehicles for a specified time interval. The software displays the movement of selected vehicles for a set period of time and selected date graphically on the base map, while also scrolling actual location information and status messaging received during that period of time on a data window. In addition, the software includes the ability to generate seven individual types of reports:

- **Detailed Event Report**: includes all events sorted by vehicle. Events recorded include locations, status changes, messages, and messages acknowledged. Events are listed in chronological order for any time period specified by the user.

- **Event Summary Report**: includes a tabulation of all activities within a specified time period and sorted by vehicle. Tabulations include the number of locations, “Off or Out of Service” messages, status changes, messages, acknowledgments, condition violations, alert messages, and “line of sight” miles traveled for each vehicle.

- **Exception Summary Report**: includes a summary of all exception conditions for a specified period of time, sorted by vehicle.

- **Message Summary Report**: includes a list of all incoming and outgoing message events.

- **Panic Summary Report**: includes a summary of all recorded panic events.

- **Stationary Vehicle Report**: includes a summary of all stationary vehicle locations for a specified period of time, sorted by vehicle. The duration of the event, time of day, and location are included.

- **Vehicle Off/Out of Service Report**: includes a summary of when the vehicle ignition is off or the vehicle is out of service during a specified day and time interval.

The software can be programmed by the user to generate reports automatically on a user-defined schedule or on an as-needed basis. Reports are either stored in a computer file or sent to a designated printer. The software does not allow the user to customize reports outside predetermined parameters. Any customization required by the user must take place on preprogrammed Fleet Director™ reports.
The Center for Urban Transportation Research

TEST SITE

The original goal of this study was to focus on automatic vehicle location technology and whether it could help to improve paratransit productivity through more efficient and effective scheduling, driver accountability, and billing practices. Specifically, CUTR proposed to use the AirTouch Teledtrac AVL technology and to apply it to Metro-Dade Transit Agency's (MDTA's) Special Transportation Services (STS) in Miami. CUTR had worked successfully with this AVL technology in a different transportation application with the City of Miami Beach (see CUTR 1994) and the vendor agreed to participate in this study. Also, MDTA was interested in participating in the study.

Metro-Dade Transit Agency

MDTA's bus and rail systems cover most of the urbanized area of Dade County, Florida. Through its Special Transportation Service, MDTA also operates door-to-door paratransit service for persons who cannot use the bus or rail systems because of a disability, as required by the Americans with Disabilities Act of 1990 (ADA). The system also provides rides for persons who are defined as transportation disadvantaged (TD); that is, those who are senior citizens, persons with disabilities, and/or children at risk, who cannot afford or do not have access to other transportation services.

In 1995, the STS program had approximately 17,000 registered clients and provided about 3,200 trips per weekday. The STS program is managed by COMSIS Mobility Services, Inc., a private company. COMSIS is responsible for taking trip reservation requests, developing schedules, and brokering trips to each of the STS paratransit operators, including MDTA's paratransit division.

Initially, CUTR had expected to use MDTA's paratransit operation as the test site for the AVL study. At the time, MDTA had plans to install AVL technology on its bus fleet and rail system; however, it had no plans to equip its paratransit vehicles with AVL equipment. Further, MDTA already had contracted for an AVL system with another vendor. This situation presented a
potential conflict as the technology that MDTA planned to install in its fleet was a GPS-based system.

After several meetings, MDTA operations staff suggested that CUTR use one of the other paratransit operators in the system, and Zuni Transportation, Inc., agreed to serve as the test site. MDTA and COMSIS both endorsed Zuni’s participation in the study and have remained informed about the overall project progress throughout the course of the research.

**Zuni Transportation, Inc.**

Prior to this study, AirTouch Teletrac’s AVL equipment and vehicle status message terminals already were installed on 20 of Zuni’s 53 paratransit vehicles. For this study, data related to time and positions of each vehicle were recorded automatically via a computer during a three-month period from mid-August through mid-November 1995. The actual locations of vehicles were compared to the expected vehicle locations, based on manifests developed by schedulers. CUTR used the data to calculate several productivity measures, including vehicle on-time performance, average vehicle dwell time, and average passenger ride time. Additionally, real-time use of the AVL system by paratransit dispatchers, as well as potential real-time application of the technology, were observed and documented throughout the research.

**System Overview**

Zuni provides more than 1,000 paratransit trips each weekday. There are approximately 55 full-time employees, most of whom are full-time drivers (42-45). In addition, Zuni employs one driver supervisor and one full-time billing clerk, who is responsible for submitting daily bills to the broker. Two full-time mechanics are on-site to ensure that Zuni vehicles are in good mechanical condition and perform regular preventive maintenance.

Zuni also employs two full-time dispatchers, who each work 10-hour shifts each day. (The billing clerk also served as the weekend dispatcher throughout the study period.) The dispatchers had the most intimate contact with the AVL system (especially the Fleet Director™ computer work station) prior to and throughout the study period. Throughout most of the study period, Zuni dispatchers conducted most of their activities within an area of approximately 200 square feet, which also housed two computers and monitors, a facsimile machine, three telephones, two
full length tables that served as work spaces, and three chairs. Within this area, dispatchers answer calls from the transportation broker, conduct real-time route changes, call passengers, communicate with drivers via two-way radios, fax information to the broker, and use the AVL computer work station for real-time monitoring of drivers and routes and real-time dispatching.

At the start of the study, space within the dispatch area was extremely limited and consequently the AVL computer work station was positioned behind the work area where most of the dispatching activity took place. This situation made it difficult for dispatchers to query the AVL software about the movement of one or several vehicles. Even following vehicle movement graphically was difficult, as dispatchers would have to physically turn around to see the computer screen. According to Zuni dispatchers, prior to the CUTR study, they used the AVL system primarily to find and plot addresses on the base map in order to direct lost drivers, to track and monitor new and problem drivers, as well as to monitor accidents and breakdowns in real-time.

**AVL Equipment Configuration**

Zuni already had installed AirTouch Teletrac’s AVL technology in 12 vans (including one wheelchair lift-equipped van) and eight sedans. Zuni estimates that the cost of outfitting each vehicle with the AVL technology and status message terminals was approximately $470 per vehicle. The AVL contract included 30 locates per unit per month, at a monthly cost of $10 per unit; additional locates were provided for 30¢ each. Therefore, prior to the study conducted by CUTR, Zuni was paying a minimum usage fee of $200 per month for the AVL service. Zuni said that the cost for additional locates beyond the 30 standard locate request was prohibitive to using the technology to its fullest potential. As part of the study CUTR negotiated a flat monthly rate of $20 per vehicle for unlimited locates, a feature Zuni elected to continue after the conclusion of the study.

**Original AVL System Design**

This part of the report describes the original AVL system design, and the modifications that were made to the software and hardware to accommodate the needs of this study. It should be noted that the AVL system originally was installed to protect the vehicles from theft. Software and
Hardware modifications made it possible to use the AirTouch Teletrac system for this paratransit productivity study.

When this study began, Zuni management indicated that although dispatchers were using the system to track and monitor drivers on a case by case basis, and to locate addresses on the electronic base map in Fleet Director™, they did not think that they were using the technology to its fullest potential. Additionally, no reports were being generated.

**AVL Status Message Terminals**

As described above, some of Zuni’s vehicles were outfitted with status message terminals. These status message terminal provide preprogrammed messages that are used to record driver status. Each time one of the customer-defined status buttons is pushed, the message associated with that button is sent to the digital transceiver and audible and visual indications are provided to show the progress of the transmitted message. According to AirTouch Teletrac’s *Fleet Director™ Digital Communications System Operation Information* (April 5, 1993) the transmission progress is indicated in the following manner:

- When a status button is depressed, the LED associated with the button begins to flash. This indicates the transceiver is in the process of transmitting the message.

- If a “busy” tone is heard, and the LED turns steady, this indicates that the transceiver is beyond the coverage area, and the operator should attempt again.

- If a single “good key” tone is heard, and the LED continues to flash, this indicates the transceiver has sent the message to the AirTouch Teletrac control center.

- When the message has been received by the control center, the LED associated with the button will turn steady, and the large LED marked “Ack” will turn on steadily. The transceiver will always transmit its location signal whenever a message has been acknowledged by the control center.

- If the message is not received by the control center, an “error” tone will be heard, and the LED associated with the switch will turn on steady.

The terminals also include a “Call” light function that allows dispatchers to alert drivers to call the office. The “Call” light illuminates to alert the driver when a message to call in is sent by the Fleet Director™ work station. The software enables the dispatcher to send a “Call” message to one, several, or all vehicles equipped with the AVL technology and status message terminals. If
the vehicle is turned off at the time the “Call” message is sent, the status message terminal will power up and illuminate the “Call” light. Message acknowledgment and vehicle location information are sent to the work station any time that the “Call” light is activated.

The status message terminal does not have an on/off power switch. Rather, the terminal automatically powers up to a ready state when the vehicle ignition is turned on. When the vehicle is turned off, the terminal remains in a standby mode, using less power than required for the ready state. When a message is received (e.g., call the office) or a button is pushed while the terminal is in standby mode, the terminal will return to ready mode. The status terminal will return to a standby state after 20 seconds of inactivity with the vehicle ignition off.

The “Ack” light is located to the right of the “Call” light and plays a crucial role in the transmission and receipt of status messages. The “Ack” light shows that the status message was successfully received at the control center. If acknowledgment is not received and a driver fails to make another attempt, the status and associated location information are lost. If acknowledgment is received, the light will remain illuminated even if the local computer work station is not logged into the control center. In this event, status messages and the associated location data will be stored for up to 10 days and forwarded to the work station the next time it logs into the network.

**Redesigned AVL System**

CUTR and Zuni first met in the fall of 1994 to discuss the overall study design. In May 1995, the team met again to review the AVL technology already in place and to discuss the details of the study. At that time it was decided that the status message terminals already installed in Zuni’s vehicles would be reprogrammed to allow CUTR to extract the data necessary for the study and to give Zuni more useful information regarding the actions and movements of its drivers and vehicles.

The group worked together to redesign the status message terminals, which was relatively easy. Once everyone agreed to the changes, the AVL vendor prepared a new template and reprogrammed the buttons. Each status button was checked to be sure it was registering properly. The original and redesigned status message terminal buttons are shown in Figures 1a and 1b.
 Button Layout Prior to AVL/Paratransit Project  
Original Status Message Terminal Display

<table>
<thead>
<tr>
<th>TIME IN</th>
<th>TIME OUT</th>
<th>PICKUP PASSENGER</th>
<th>DROPOFF PASSENGER</th>
<th>AVAILABLE FOR CALL</th>
<th>BEHIND SCHEDULE</th>
<th>NEED HELP MECHANIC</th>
<th>NEED HELP 911</th>
</tr>
</thead>
<tbody>
<tr>
<td>call</td>
<td>ack</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>light</td>
<td>light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOP ROW:**

- **TIME IN**: press when arriving at the garage
- **TIME OUT**: press when leaving the garage
- **PICKUP PASSENGER**: press when arriving to pick-up passenger(s)
- **DROP OFF PASSENGER**: press when arriving to drop-off passenger(s)

**Figure 1b. Redesigned Status Message Terminal Display**
Button Layout for AVL/Paratransit Project
Final Status Message Terminal Display

<table>
<thead>
<tr>
<th>ARRIVE PICK-UP</th>
<th>LEAVE PICK-UP</th>
<th>WHEELCHAIR</th>
<th>ARRIVE DROP-OFF</th>
<th>LEAVE DROP-OFF</th>
<th>NO SHOW</th>
<th>REFUSED TRIP</th>
<th>WRONG ADDRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>call</td>
<td>ack</td>
<td></td>
<td>CANCEL ENTRY</td>
<td>AVAILABLE FOR CALL</td>
<td>INFO HELP</td>
<td>MECH HELP</td>
<td>EMERGENCY HELP</td>
</tr>
<tr>
<td>light</td>
<td>light</td>
<td>WHEELCHAIR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOP ROW:**
- **ARRIVE PICK-UP**: press when driver arrives at pick-up address
- **LEAVE PICK-UP**: press when driver is done loading passenger(s) and is leaving pick-up address
- **WHEELCHAIR**: (wheelchair user) press when leaving pick-up address AND when arriving at drop-off address
- **ARRIVE DROP-OFF**: press when driver arrives at drop-off address

**Figure 1b.** Redesigned Status Message Terminal Display
Each time a driver presses a status button on the terminal, an acknowledgment should be received from the control center in Fort Lauderdale. The unique status (e.g., Arrive Pick-up) associated with that button, a time and date stamp, and the vehicle’s location, are transmitted to the AVL computer work station at Zuni, where the information is displayed on a screen in both text and graphical form, as well as saved to a computer file for report generation.

The first two buttons on the top row of the redesigned terminal (Arrive Pick-up, Leave Pick-up) correspond to the pick-up portion of a one way trip. The “Wheelchair” button is pressed each time a passenger using a wheelchair boards or alights from the vehicle. The “Arrive Drop-Off” and “Leave Drop-Off” buttons correspond to the drop-off portion of a one-way trip. The remaining buttons on the first row of the terminal (No Show, Refused Trip, Wrong Address) provide additional descriptions of the trip type. The buttons located on the bottom row of the terminal (Cancel Entry, Available for Call, Information Help, Mechanical Help, Emergency Help) provide information on the status of the vehicle. This message configuration enabled CUTR to capture the information necessary to examine the productivity attained by Zuni drivers and provide rich data to Zuni management and staff to assist in real-time decisions about route changes and schedule adjustments. It also provided a tool to aid in more responsive customer service activities.

**AVL Service Enhancements**

In addition to reprogramming Zuni’s status message terminals, CUTR worked with Zuni and AirTouch Teletrac staff to provide several other service enhancements that would benefit both Zuni and CUTR’s study.

The AVL schedule was set to locate vehicles every two minutes from 5:00 a.m. to 7:00 p.m., Monday through Friday, and every 30 minutes after 7:00 p.m. weekdays and during weekends. The software allows the user to set the locate schedule for intervals as short as every two seconds. Location data also were recorded each time a driver pressed a status button on the message terminals and received acknowledgment from the control center. Sessions with AirTouch Teletrac trainers also were scheduled to train Zuni’s dispatchers and CUTR’s project staff to use the Fleet Director™ software to manage the AVL-equipped vehicles. Finally, CUTR supplied Zuni with a 17-inch computer monitor to be used for the duration of the research. This monitor enhanced the graphic clarity of the software making it easier to use the AVL data for real-time dispatching activities.
A major problem encountered by CUTR project staff in the beginning of the project was determining which Zuni vehicles were actually equipped with functioning AVL technology. The original equipment was installed in December 1993 and February 1994. At that time, the subcontractor's installation claim forms were completed, which listed the vehicle year, make, license number, vehicle identification number, and the installed vehicle location unit's catalog number and unique identification number. This information provided a record of the vehicles equipped with the AVL technology. This information is also entered into the Fleet Director™ software and VLU numbers are assigned to the proper vehicles in the computer. This step is critical as the AirTouch Teletrac control center uses the VLU number recorded in the Fleet Director™ software to locate and track their customers' vehicles.

However, it became evident that both the installation forms and the VLU assignments in the computer at Zuni contained several mistakes which were resulting in bad locate data. The installation claim forms contained incomplete and/or incorrect information for four of Zuni's vehicles, including incorrect vehicle numbers. The same types of mistakes were found in the Fleet Director™ vehicle assignments. These mistakes resulted in location information for vehicles that could not be identified. To remedy the problem, Zuni's mechanics and CUTR project staff pulled the AVL units from each vehicle and recorded the accurate VLU. The information on the installation claim forms was then updated for Zuni's records and corrections were made to the AVL software.

By late July 1995, the necessary AVL equipment repairs and installation had been completed by the AVL vendor's technician. At that point CUTR project staff began working with Zuni management to complete driver training as part of the research project. Although many of Zuni's drivers had been working in vehicles that had status message terminals installed, none had been trained to use the terminals prior to the CUTR study. Therefore, drivers needed to receive training on how to use the terminals and the level of effort expected of them.

Software Changes

Early in the project, CUTR also found problems with the locate data being recorded by the Fleet Director™ software. Based on the vehicle numbers, which serve as vehicle identifiers displayed on the software map, some vehicles were being tracked by the AVL system that were not listed as having AVL technology installed. This was a result of mistakes made in the assignment of
vehicle numbers and VLUs in the Fleet Director™ software and was rectified as soon as the corrections were made.

Additionally, a considerable number of error messages were being received in place of location data. For example, quite often the AVL software was reporting “vehicle off or out of service” and “marginal coverage, please try again later.” Discussions about this problem with company representatives early on in the study did not bring about any resolution to this problem. The AVL company sent a technician to Zuni to test the equipment, which revealed several programming problems with the status message terminals, as well as some bad equipment. Several more visits to Zuni were required to resolve these problems. Despite these efforts, error messages continued to be a problem throughout the study.

Staff Training

Any new technology is only useful if people are trained to use it properly and have a thorough understanding of the purpose for, and intended results of, using the new technology. Therefore, CUTR staff and Zuni dispatchers, drivers, and managers were trained to use the AVL equipment as part of this project. Initially, CUTR staff and Zuni’s dispatchers and managers were trained at the AirTouch Teletrac facilities in Fort Lauderdale. Subsequent on-site training was given to the dispatchers, driver supervisor, and drivers at Zuni. Particular attention was given to dispatcher and driver training because their use of the equipment was critical to the data collection needed for analysis.

Dispatcher Training

Zuni dispatchers were trained on how to use the AVL software and computer work station at Zuni. Dispatchers were shown the various graphical and text-based information windows in the software. CUTR staff instructed dispatchers on how to track one, several, or all of the vehicles equipped with AVL technology. Training was given regarding how to monitor the progress of a vehicle on its scheduled route by monitoring the vehicles’ status received from the status message terminals. Instruction also was given on how to generate the various types of AVL reports for selected days, times, and vehicles. Additionally, dispatchers were instructed to log into and out of the AVL control center at the same time each day to ensure consistent data for the study.
Driver Training

CUTR initially proposed to conduct the driver training; however, because there are no regularly scheduled group meetings, most of the drivers training was conducted by the driver supervisor when drivers came into work in the morning. CUTR did participate in the first round of training when a hurricane threat provided an opportunity to have many of Zuni’s drivers in one place for training as they waited for direction regarding potential evacuation services. CUTR took this opportunity to conduct preliminary training on how to use the status message terminal. Zuni’s driver supervisor translated the instructions into both English and Spanish to ensure that all drivers understood the information. Subsequently, the driver supervisor conducted one-on-one training with each of the drivers who would be using vehicles with AVL units installed.

CUTR developed a one-page guide for the drivers to reference following the training (see Figures 2a and 2b). The guide was printed in English and Spanish, using fluorescent yellow paper that was laminated for durability. The guide described the specific sequence of buttons to be pushed for each type of pick-up or drop-off. The guide also included a description of each of the status message terminal buttons and indicator lights. The training sessions also provided explanations of the audible tones that accompany the pushing of the buttons.

Driver Testing and Onboard Accuracy Checks

Zuni’s management asked CUTR to develop a test for the drivers using the AVL status message terminals. The test gave drivers various trip scenarios and then asked them to press the correct sequence of status buttons for each situation presented. Questions also were included about the order and purpose of the various terminal functions. The test was administered orally by Zuni’s driver supervisor. A copy of the driver test is included in Appendix A. Most drivers who were regularly assigned to drive AVL-equipped vehicles understood how to use the buttons and did well on the test.

CUTR also conducted onboard accuracy checks after the drivers had been using the status message terminals for several weeks. The purpose of the checks was to observe driver activity as it related to passenger pick-ups and drop-offs. The sequence of buttons on the status message terminals pressed by the Zuni drivers and the data recorded by the AVL system were compared.
Directions for Utilizing Teltrac
Zuni Transportation

**PASSENGER PICK-UP**
- When the vehicle stops at the pick-up address, press "ARRIVE PICK-UP".
- When leaving pick-up site, press "LEAVE PICK-UP" AND button marked "WHEELCHAIR" for each passenger using a wheelchair (e.g., if two passengers are using wheelchairs, press button two times).

**NO SHOW PASSENGER PICK-UP**
- When the vehicle stops at the pick-up address, press "ARRIVE PICK-UP".
- After determining passenger(s) is a "no show", press "LEAVE PICK-UP" AND "NO SHOW" for each "No Show" passenger.

**REFUSED TRIP PASSENGER PICK-UP**
- When the vehicle stops at the pick-up address, press "ARRIVE PICK-UP".
- If passenger refuses trip, press "LEAVE PICK-UP" AND "REFUSED TRIP" and leave.

**WRONG ADDRESS PASSENGER PICK-UP**
- When the vehicle stops at the pick-up address, press "ARRIVE PICK-UP".
- If driver thinks the pick-up address is wrong, press "INFO HELP" and call dispatch for instructions.
- If pick-up address is wrong, press "LEAVE PICK-UP" AND "WRONG ADDRESS" and follow dispatcher's directions.

**PASSENGER DROP-OFF**
- When the vehicle stops at the drop-off address, press "ARRIVE DROP-OFF".
- When leaving drop-off address, press "LEAVE DROP-OFF" AND button marked "WHEELCHAIR" for each passenger that is using a wheelchair (e.g. if two passengers using wheelchairs exit vehicle, press W/C button two times).

**CANCEL ENTRY**
- If the driver presses a wrong button, press "CANCEL ENTRY" (cancel entry). *Pressing this button cancels only previous action.*

**AVAILABLE FOR CALL**
- Press "AVAILABLE FOR CALL" when driver has a gap in schedule and is available to pick-up passengers.

**MECHANICAL PROBLEMS**
- If vehicle breaks down, press "MECH HELP" and call dispatch for help.

**EMERGENCY PROTOCOL**
- Press "EMERGENCY HELP" and call dispatch if there is an emergency (accident, passenger problem, etc).

**CALL LIGHT**
- This call light (located in the bottom left corner of pad) lights when dispatch wants the driver to call in OR when dispatch acknowledges the driver has pressed a help button (INFO HELP, MECH HELP, EMERGENCY HELP).

**ACKNOWLEDGMENT LIGHT**
- The "ACK" lights up after each button is pressed to record action. This light must illuminate before driver may press the next button.

Figure 2A: Driver Instructions (English)
Direcciones para Utilizar Teletrac
Zuni Transportation

RECOGIDA DE PASAJERO (Passenger Pick-Up)
- Llegar a la recogida, presione "ARRIVE PICK-UP".
- Saliendo de la recogida, presione "LEAVE PICK-UP" y presione "WHEELCHAIR" si el cliente está en una silla de rueda. (Ej., Si hay dos silla, presione "WHEELCHAIR" dos veces.)

CLIENTE NO SE ENCUENTRA (No Show Passenger Pick-Up)
- Llegar a la recogida, presione "ARRIVE PICK-UP".
- Después de determinar que es un NO SHOW, presione "LEAVE PICK-UP" y "NO SHOW" por cada pasajero que es NO SHOW.

CLIENTE SE NIEGA A VIAJAR (Refused Trip Passenger Pick-Up)
- Llegar a la recogida, presione "ARRIVE PICK-UP".
- Si el cliente no quiere viajar porque no puede subir en un van o porque la dirección que va es incorrecta, presione "LEAVE PICK-UP" y "REFUSED TRIP".

DIRECCION INCORRECTA (Wrong Address Passenger Pick-Up)
- Llegar a la recogida, presione "ARRIVE PICK-UP".
- Si el chofer cree que la dirección es mala, presione "INFO HELP".
- Si la dirección en el manifesto está mal, notificar al dispatcher y presione "LEAVE PICK-UP" y después presione "WRONG ADDRESS".

DESTINO DE PASAJERO (Passenger Drop-Off)
- Llegar al destino del cliente, presione "ARRIVE DROP-OFF".
- Saliendo del destino del cliente, presione "LEAVE DROP-OFF".
- Si el cliente es un wheelchair, presione "WHEELCHAIR" por cada pasajero en silla.

CANCELAR ENTRADA (Cancel Entry)
- Si se toca un botón incorrecto, presione "CANCEL ENTRY". Presionado este botón cancela la acción anterior solamente.

DISPONIBLE PARA LLAMADA (Available for Call)
- Presione "AVAILABLE FOR CALL" cuando el chofer tiene tiempo en su ruta para aceptar otros trabajos.

PROBLEMA DE MECANICA (Mechanical Problems)
- Presione "MECH HELP" cuando hay problema con el vehículo.

EMERGENCIA (Emergency Protocol)
- Presione "EMERGENCY HELP" cuando hay una emergencia como un accidente o problema con un pasajero.

LUZ EN LA MANO IZQUIERDA BAJA DEL PANEL (Call Light)
- Cuando esta luz está encendida es que el dispatcher te está localizando por favor llamar a la base.

LUZ DE CONOCIMIENTO (Acknowledgement Light)
- El "ACK" luz se enciende cuando se ha presionado un botón y es prueba que el sistema reconoce la acción. La luz tiene que encender antes de poder tocar otro botón.

Figure 2B: Driver Instructions (Spanish)
At the same time, CUTR conducted informal interviews with the drivers regarding how the terminals were working, how they felt about using AVL technology, and problems, concerns, or comments related to using the system. Drivers contributed a great deal of information. Drivers said they sometimes forgot what they were supposed to do. They also admitted they sometimes forgot to push the buttons until they were already moving or completely forgot about using the status message terminals.

Many of the comments made by the drivers seemed to indicate that the driver training was not comprehensive enough. All of the drivers who were interviewed commented that no one had ever explained the purpose for using the status message terminal or the purpose for the study. Other comments indicated that clear instructions were not always offered regarding the sequence of buttons to push, such as pressing the “No Show” button each time a passenger was considered a no show. Finally, driver suggestions regarding additional status buttons that they felt would be useful revealed that the meaning of each of the status buttons on the terminals were not clearly understood. (Most of the suggestions for additional button functions actually were already available from the existing status buttons, but the drivers did not appear to fully understand the uses of the vehicle status buttons.) Clearly, additional training should have been provided to explain the project and ensure that drivers were completely familiar with use of the status message terminals.

AVL Equipment and Data Concerns

Early in this project it became apparent to the study team that AVL equipment and software problems were impacting the data quality generated by the system including: (1) lack of acknowledgments, (2) error messages, (3) incomplete status information, (4) automatic locate schedule, and (5) vehicle speed readings. Given these concerns, CUTR scheduled a meeting with representatives from the vendor and Zuni management to discuss the technological concerns.

Lack of Acknowledgments

The issue causing the greatest concern for the AVL study was the apparent lack of acknowledgment from the AVL control center. Drivers had complained that they only "sometimes" receive acknowledgment after pushing a button. The onboard accuracy checks
revealed that drivers often were not receiving acknowledgment from the control center. However, the occurrences did not appear with any consistency or pattern. For quite some time the CUTR staff thought (and AirTouch Teletrac representatives agreed) that when drivers were not receiving acknowledgment, it might be related to the physical location of their vehicle (i.e., the vehicle was located in the most southern portion of the service area or in an urban canyon, etc.). However, on-board accuracy checks revealed no set pattern or specific area(s) related to the lack of acknowledgment from the control center. CUTR placed a very high priority on the resolution of this problem, as the lack of acknowledgment from the AirTouch Teletrac control center and the subsequent loss of data resulting from this situation would negatively impact the result of our study and the potential application of this particular technology in paratransit.

At a meeting among CUTR, Zuni, and AirTouch Teletrac staff, the AVL vendor suggested that the reason that Zuni was having so much trouble receiving acknowledgment from the control center was because of the type of antennas installed in Zuni’s vehicles. He explained that Zuni was using internally hidden, pancake-type antennas with its VLUs. According to the AVL vendor representatives, this type of antenna is not appropriate for messaging; rather, it is intended to be used for vehicle location purposes only. The AVL technician also indicated that human bodies can also absorb part of the signal from the hidden antennas, thus making the signal weaker, further reducing successful data transmission to the control center.

In an attempt to obtain better data for the study, the AVL vendor temporarily installed external antennas on the vehicles included in the study sample. CUTR project staff hoped that the external antennas would enhance the quality of the data collected for the study; however, subsequent review of the data generated from the vehicles with the external antennas revealed only slight improvement.

**Error Messages**

The second major concern was the excessive number of “Marginal Coverage” and “Vehicle Off or Out of Service Area” error messages being received in place of location information from the AVL control center. Zuni’s work station was receiving these messages instead of vehicle locations quite often and had been since the beginning of the study. As with the lack of acknowledgments from the control center, the occurrences were quite inconsistent and did not appear to be related to particular areas.
The large number of error messages was a matter of concern for CUTR project staff as the lack of location information places limitations on the usefulness of this particular technology for tracking paratransit vehicles for the purpose of real-time dispatching, scheduling, billing, and customer service. In order to evaluate the effectiveness of the technology, a clear understanding of the limitations (physical, environmental, spatial, etc.) would be necessary.

The AVL representatives clarified that the "Marginal Coverage" message occurs if the control center receives information only from one or two of the radio towers (instead of three), which is not enough information to determine an accurate location. Also, the vendor believed that the "Vehicle Off or Out of Service" message was, in Zuni's case, a result of using the hidden pancake-type antennas. Finally, AVL representatives stated that when this message occurs in bunches, there probably is a problem at the main control center. Review of the data collected after the installation of the external antennas did show a decrease in the number of "Vehicle Off or Out of Service Area" error messages.

Incomplete Status Information

A third concern was incomplete status information. A review of the data being collected by the AVL software prior to the meeting also showed that Zuni was sometimes receiving incomplete status information in the reports that Fleet Director™ generated. According to the AVL vendor, status message button information recorded at the work station should include three parts: (1) status message button pushed (e.g., "Arrive Pick-up"), (2) driver status changed, and (3) location of the vehicle at the specific time the status button was pushed.

Review of the AVL-generated data revealed that often all three pieces of information were not being received. If the driver's status had not changed since the last button that was pressed (e.g., pushed the "Wheelchair" button multiple times), a line that indicates "driver status changed" was not being included (this did not present a problem for the research). Additionally, sometimes the status information included a "vehicle off or out of service area" or "marginal coverage" for the location data. This was problematic, but really could not be avoided unless the lack of acknowledgment issue was dealt with. However, sometimes the information accompanying a status indicator did not include any reference to the vehicle's location. Unfortunately, the status information is rendered useless if there is no indication of where the vehicle was located at the time that the status button was pressed.
Automatic Locate Schedule

A fourth concern was inconsistencies in the automatic locate schedule. Although Zuni’s vehicles were scheduled to be polled for their locations every two minutes from 5:00 a.m. to 7:00 p.m. Monday through Friday, a review of the Detailed Event Reports for the study’s sample vehicles showed that the vehicles were not always being automatically located beginning at 5:00 a.m., as programmed. One possible explanation was that the Zuni dispatchers were not logging into the control center at 5:00 a.m. each morning, as was requested of them. However, CUTR project staff observed that this situation was occurring even when the dispatchers had logged into the control center at the proper time. Also, in some cases only one or two of the vehicles were not located until the afternoon, even though all other vehicles had been automatically located for several hours. Prior to the meeting CUTR project staff checked the locate schedule at Zuni via PC Anywhere and the system was configured correctly.

The AVL software support representative said he thought the problem resided in the locate schedule and visited Zuni to check the automatic locate schedule set up for Zuni’s vehicles. During the site visit, the Fleet Director™ computer work station was logged into the AirTouch Teletrac control center properly and no problems were found with Zuni’s automatic vehicle location schedule, yet no vehicles were being located. The AVL technicians were not able to resolve this problem or explain the cause.

Vehicle Speed Readings

The final data concern to be addressed at the meeting was the accuracy of speed readings being recorded by the AVL software. Concern focused on location data that accompanied speed reports of 80 or more miles per hour in a residential area with stop signs at every block. The vendor clarified that vehicle speed readings are only an approximation, average speed. They are measured from latitude/longitude to latitude/longitude. If speed readings from exact points are desired, the automatic locate schedule must be set to locate the vehicles every 10 or 15 seconds, rather than every two minutes.
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DATA COLLECTION

This section describes the sample data and resultant usable data collected for this project. For this study, CUTR examined the use of one type of AVL technology, the AirTouch Teletrac subscriber-based radio navigation system, in one paratransit operation in Miami, Florida. CUTR project staff collected AVL location and vehicle status data from selected vehicles operated by Zuni Transportation. The data were then used to analyze on-time performance, dwell time, and average travel time for a sample of four vehicles providing service during 11 sample days. In addition, real-time observations of the use of the AVL system by dispatchers and drivers, as well as informal interviews with Zuni staff, revealed many potential applications of the technology. Possible drawbacks to the specific AVL technology used in this study also were evaluated.

Sample Data

Zuni’s AVL-equipped vehicles were located automatically every two minutes using the AVL software. This schedule was set by CUTR so that vehicles could both be tracked in real-time by Zuni dispatchers and their movement monitored through Fleet Director™ reports for later analysis. Initially, the automatic locate schedule was set to locate each vehicle every 30 seconds; however, the schedule was adjusted to two-minute intervals because of the large volume of data being collected. The vehicles also were located each time a button on the onboard status message terminal was pressed. This information enabled CUTR (and Zuni) to monitor whether vehicles were where they were scheduled to be at the correct time.

Vehicle Sample

Although data from Zuni’s AVL-equipped vehicles were collected throughout the research period, a subset of eight vehicles was initially selected to be the focus of detailed data analysis. A sample was chosen to make the data more manageable within the study time frame and budget. CUTR project staff worked with Zuni dispatchers to select a sample of vehicles that would be representative of the paratransit service provided by the company. Vehicle types, route
regularity, and driver experience were all considered in the selection of the initial vehicle sample. The initial sample included two 15-passenger vans, with one regular (repetitive) route and one demand-response (random) route; two lift-equipped vans, with one regular route and one demand-response route; and four sedans with two regular routes and two demand-response routes.

The initial sample was changed after one month of data collection to reflect changes in Zuni’s route schedules and vehicle assignments. In addition, some of the vehicles in the initial sample had driver assignments that changed regularly. Originally it was thought that a variety of drivers would be a useful aspect of the study; however, as the study progressed it became clear that drivers untrained in the use of the status message terminals were being assigned to sample vehicles, resulting in significant amounts of data being lost and contributing to unusable data for the AVL study. In an attempt to obtain better data the vehicle sample was altered to include seven vehicles: three 15-passenger vans, two lift-equipped vans, and two sedans. All of these vehicles had consistent driver assignments and all of the drivers were trained to use the status message terminals.

However, as CUTR began preparing the data for analysis, it became clear that several drivers included in the sample of seven vehicles had not been using the status message terminals. Therefore, three of the sample vehicles were discarded from the final data sample. The final data sample of four vehicles remained representative of the transportation services provided by Zuni as the sample still contained one 15-passenger van, one wheelchair lift-equipped van, and two sedans.

**Data Sample**

Four months of AVL data and driver manifests were collected from Zuni between August 1 and November 30, 1995. The sample period was chosen to allow for comparison of the data collected prior to and following installation of the external antennas (as described in the previous section) to compare the accuracy and reliability of the AVL technology.

The month of August, was used to familiarize personnel with the AVL system and data reporting. Beginning with September 1, 1995, every fourth weekday was selected for inclusion in the actual data sample. If driver manifests were not available, the next weekday with vehicle
information was selected. This schedule also assured that data would be collected from different
days of the week. Eleven days between September 1 and October 30, 1995, were included in the sample:

- September 1 Friday
- September 7 Thursday
- September 13 Wednesday
- September 19 Tuesday
- September 25 Monday
- September 29 Friday
- October 5 Thursday
- October 11 Wednesday
- October 17 Tuesday
- October 23 Monday
- October 30 Monday

Aside from the real-time graphical and text displays of the vehicle location data and vehicle
status information on the AVL computer workstation, all of the information was automatically
stored in a vehicle history computer file for later data analysis and report generation. CUTR
retrieved the history file from Zuni’s computer each week via a high speed modem and PC
Anywhere software. The files were archived on computer disks and kept for subsequent analysis.

CUTR used the vehicle history files to generate Detailed Event Reports with the Fleet Director™
software for each of the sample vehicles (see Appendix B). The Detailed Event Reports
contained data concerning all of the recorded movements and actions of each of the sample
vehicles from 5:00 a.m. to 7:00 p.m., Monday through Friday. Included in the reports were
vehicle identification number, speed and direction, date, time, vehicle status, and vehicle
location. Detailed Event Reports that contained AVL data for each of the sample vehicles for
each sample day were saved in ASCII computer file format so the information could be analyzed
using other software programs.

Driver Manifest Sample

Zuni also provided CUTR with copies of completed driver manifests for each of the vehicles
included in the study sample. Among other information, the manifests include the scheduled
pick-up and drop-off times, origins and destination addresses, the unique trip number for each
pick-up and drop-off, and the trip type (i.e., wheelchair or ambulatory). Drivers manually record
pick-up times, drop-off times, odometer readings, and other information.
Data Interface

Several steps were required to complete the data analysis, a process which was time-consuming because of the need to manually incorporate data from two different sources—the AVL locate and status information, and the COMSIS-generated driver manifests. The first step in the data analysis was to manually match vehicle trips as indicated by the AVL data in Detailed Event Reports with trips listed on the driver manifests so that comparisons could be made among scheduled events, times recorded by the driver in the manifest, and status messages recorded by the driver using the onboard AVL status message terminals. This was necessary because the information obtained from the status message terminals did not include any information that would uniquely identify person trips.

(Because the AVL system used for this study was not specifically designed for this application and because not all data from drivers’ manifests are entered into the computer, we were unable to make a direct computer link between the AVL software and COMSIS paratransit software. This problem could be avoided by designing an interface between the AVL software and scheduling software prior to implementing a new system.)

Upon reviewing the initial AVL data, CUTR found that much of the accumulated data was repetitive because of the automatic location polls occurring every two minutes. To reduce the amount of unneeded data and to make the data more manageable, a program was written in BASIC that deleted all location polls that were the same as the previous location (i.e., the vehicle had not moved since the previous locate). The data contained in the Detailed Event Reports were refined with the BASIC program so that only the information necessary to track a vehicle’s movement remained.

The remaining AVL data were then imported into Lotus 1-2-3 spreadsheets. The information recorded from the onboard status message terminals was matched with trip information contained in the drivers’ completed manifests. Five columns were added to the spreadsheet to accommodate the manually recorded information collected from the manifests:

- Trip number (the unique trip identifier).
- Scheduled pick-up time.
- Driver recorded pick-up time.
- Scheduled drop-off time.
Driver recorded drop-off time.

After the manual matching of AVL trips to assigned trips was completed, the spreadsheets were sorted by unique trip number so that each passenger’s trip information was grouped together for analysis. The remaining data were saved in ASCII format. Finally, a second BASIC program was written to perform the necessary calculations to determine on-time performance, vehicle dwell time, and passenger travel time for each trip included in the sample.

**Usable Data**

Table 2 provides the results of the comparison of the expected status data (based on completed driver manifests) and the actual status data recorded by the AVL technology (as determined by using detailed event reports).

The table shows statistics for each of the four vehicles included in the final data sample. The data have been broken out by sample day and status button function (see Figure 1b). Totals are included for each vehicle status, day, vehicle, and grand totals. The expected data (from manifests) were compared to actual data (from AVL data), and averages were calculated. If Zuni did not provide completed driver manifests for a vehicle on one of the sample days or no AVL data was recorded, that sample day for the vehicle was discarded entirely.

**Complete Trip Information**

Overall, the AVL technology captured 73 percent of the expected trip data, based on a comparison with completed driver manifests. A review of Table 2 reveals the differences in the percentage of complete trip information captured from the four vehicles included in the final sample. For example, vehicles #119 and #201 yielded 85 percent and 92 percent of the expected data, respectively. Both vehicles are large vans; #201 is lift-equipped. In both cases, the lowest complete data score was obtained for the “No Show” status button. The AVL data from both of these vehicles recorded the occurrence of this trip outcome at 63 percent of the expected occurrence.
The data for vehicles #303 and #429 resulted in significantly lower percentages of actual data recorded compared with the expected data. Vehicle #303 had an overall score of 53 percent and Vehicle #429 had an overall score of 54 percent. Interestingly, vehicle #429 demonstrates a significant decline in data obtained after the external antennas were installed. The percentage of data obtained from vehicle #303 remained relatively constant throughout September and October, suggesting that the external AVL antennas may not have been a significant factor in the loss of data.

Several factors potentially account for the discrepancy between the expected data and the actual data obtained. As was discussed earlier, limitations in the AVL equipment related to the particular applications in this study, may account for some of the loss of location and status data. The level of status messaging attempted for the demonstration at Zuni was not typical of the services provided by AirTouch Teletrac. The intensity of the data collection necessary to obtain complete trip information for an examination of paratransit productivity may be beyond the capabilities of this particular type of AVL technology.

Further, some AVL data were not included in the data sample because the information could not be matched with a trip listed on driver manifests. The location data from the AVL technology listed the street where the vehicle was located at the time that the status button was pressed. The vehicle’s actual position was indicated by the two nearest cross streets. Data concerning where the vehicles were supposed to be were shown on the completed driver manifests as an exact street address. Occasionally, it was not possible to determine if the data from the AVL technology corresponded to the data from the completed manifests. One explanation for this situation is that the Etak™ map included with the Fleet Director™ software uses some street names that are no longer valid. Compounding this situation is the fact that many streets in the Miami area are known by several different names (e.g., Bird Road is the same as 40th Street SW).

**Data Limitations**

Before proceeding to the findings, it is important to discuss several other limitations evident from the sample data collected. One goal of the study was to examine the application of the particular type of AVL technology and service offered by AirTouch Teletrac in particular. To address this goal, it was necessary to compare the data obtained by the AVL technology installed in Zuni’s
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Summary of Detailed Event Reports

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**Total:**

|               | 696 | 217 | 715 | 680 | 405 | 72% | 639 | 450 | 72% | 630 | 426 | 67% | 258 | 236 | 91% | 46 | 26 | 64% | 1 0% | 2955 | 2158 | 73% |

Sources: AVL data and manifest information collected in September & October 1995 from Zuni Transportation.
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vehicles with information from the completed manifests. This task was accomplished by manually counting the expected occurrence of "Arrive Pick-up," "Leave Pick-up," "Arrive Drop-off," "Leave Drop-off," "Wheelchair," "No Show," and "Refused Trip," indicated on the completed driver manifests.

The remaining status indicators on the status message terminals provided supplementary information regarding vehicles' progress. These figures were then compared to the data that were actually recorded by the AVL software. Only complete trip data were counted for the comparison (e.g., status information without location data was discarded from the sample). Likewise, any status information that could not be manually matched with a person trip as indicated on the completed driver manifests was discarded from the sample. The focus was on data that could be used for service monitoring purposes.

As discussed previously, the task of manually matching person trips from the completed driver manifests to vehicle trips from the AVL-recorded data revealed that drivers on several of the seven sample vehicles had not been using the status message terminals. As a result, three of the seven sample vehicles were discarded from the final data sample.

**AVL Software and Hardware Limitations**

Lack of acknowledgment from the AVL control center after pressing a button on the status message terminals on board the vehicles may account for some loss of data in the demonstration. In the event that acknowledgment is not received after a status button has been pressed, all the data connected with that action is lost. Receipt of "marginal coverage" or "vehicle off or out of service" error messages also result in the loss of data. Specifically, these messages occur in place of a vehicle’s location data so that the vehicle status data is rendered useless.

As described earlier, external antennas were installed on seven vehicles in October 1995, in an attempt to improve the AVL and vehicle status data collected by reducing lack of acknowledgment and error message occurrences. Data collected during September 1995 were obtained with the internal, pancake-type antennas. Data for October 1995 were obtained with the external antennas temporarily installed on the sample vehicles in an effort to improve the data received. Comparison of the September and October data for vehicles #119 and #201 do not reveal any significant differences in terms of the percent of actual data recorded and the data that was expected based on completed driver manifests.
Additional potential equipment difficulties could help to explain the discrepancy between the AVL data that was expected and the data that was actually accumulated. Status information was occasionally received that lacked any reference to the vehicles’ location. Without the location data, it was impossible to manually match the vehicle trip with the corresponding person trip so the data had to be discarded from the sample. In addition, an unexplained problem with the automatic locate schedule resulted in the loss of all AVL data for several hours on several days throughout the demonstration period.

**Human Error**

Human error also may explain discrepancies between some of the data expected and the data received for Zuni. Interviews with drivers during the onboard accuracy checks revealed that drivers often forgot to press the necessary status button on the status message terminals. According to drivers, they sometimes would remember to push the status button indicating that they had arrived at a destination, but forget to indicate when they were leaving or vice versa. Additionally, drivers admitted, and a review of the AVL data confirmed, that sometimes they would not press the status buttons until they had departed and were in route to their next destination. These data had to be discarded from the sample as it was impossible to match the status location data with the address information contained on the completed driver manifests.

Data may also have been lost if Zuni dispatch did not log into the control center at 5:00 a.m. each weekday. The exact reason(s) for the failure to log into the control center could not be substantiated during field visits by CUTR project staff.

The Fleet Director™ software requires that each vehicle being tracked be described in the database and assigned to the map and data windows. Conversely, customers may add or delete vehicles from the windows if they do not wish to collect data for the vehicles. On several occasions, vehicles were inadvertently deleted from the map and data windows, resulting in lost data. The work station at Zuni was in an area of heavy activity and many individuals had access to the computer each day. In order to resolve this problem, CUTR placed a password on the vehicle assignment function in the software, which corrected the problem. Only CUTR project staff and Zuni management had access to this function.

Missing manifests also contributed to the lost trip data. On several occasions, Zuni staff forgot to send requested manifests to CUTR. Once discovered it was too late to easily retrieve a copy
of the manifest, which had been submitted to the broker for billing purposes. Also, trips that were added to a driver's route during the day are documented on add-on forms, which are filled out by drivers and turned in along with the completed driver manifests at the end of each day. On several occasions, Zuni did not forward the add-on forms to CUTR; therefore, the vehicle status information from these trips could not be included in the data sample.
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FINDINGS

The original goal of this research was to determine whether the application of AVL technology to paratransit could help to improve system productivity. Two primary approaches were used to analyze the potential impact of AVL applications on paratransit system productivity: (1) an analysis of paratransit performance measures and (2) an analysis of potential real-time AVL applications.

Performance Measures and System Productivity

AVL technology has just recently begun to be applied to the paratransit field. Implementing this type of technology may help to improve paratransit productivity through better scheduling and routing practices, reduced ride time, and enhanced real-time customer service. For this study, CUTR examined the application of AVL technology to paratransit by looking at how the technology might be used to improve system productivity. Three performance measures were chosen to represent system productivity:

- **On-time performance**: whether the vehicle arrives at the scheduled pick-up time and delivers the passenger at the scheduled drop-off time.

- **Vehicle dwell time**: the elapsed time from when the driver arrives to pick-up a passenger and leaves the pick-up location; as well as the elapsed time from when the driver arrives at the drop-off location and leaves after dropping-off the passenger.

- **Travel time**: the elapsed time from when the vehicle leaves the passenger’s pick-up location and arrives at the passenger’s drop-off location.

Ideally, to measure the effectiveness of any new technology, a comparison would be made between the system’s productivity prior to the introduction of the new technology and the productivity after introduction of the new technology. In the ideal world, all other aspects of the system would be held constant to allow for a perfect comparison (e.g., vehicles, drivers, weather, routes, etc.). However, in the real world, perfect comparisons rarely can be made. To further complicate matters, in this case the AVL technology that was available could not be interfaced
directly with the scheduling software, resulting in data analyses being made well after actual events, instead of in real-time.

Given this scenario, CUTR decided to apply the data analysis in a slightly different way; that is, to use the available data to determine differences among what was scheduled, what the driver recorded on his or her trip manifest (log), and what was recorded (by the driver) using the AVL equipment and captured in Detailed Event Reports generated by Fleet Director™ software.

Overview

A summary of the results of the performance measures analysis is shown in Table 3. The table includes the following information:

- **Columns A-C**: average on-time performance for passenger pick-ups as recorded by the driver (Log) and as recorded using AVL equipment (AVL). The Log and AVL entries were compared to the scheduled pick-up time (Sch) and to each other.

- **Column D**: average pick-up dwell time (i.e., the amount of time the vehicle was stationary at the pick-up location while waiting for and/or loading passengers). Pick-up dwell time is measured from the time of arrival to the time of departure at the pick-up location, as recorded by the AVL equipment.

- **Columns E-G**: average on-time performance for passenger drop-offs as recorded by the driver (Log) and as recorded using AVL equipment (AVL). The Log and AVL entries were compared to the drop-off time scheduled (Sch) by COMSIS and to each other.

- **Column H**: average drop-off dwell time (i.e., how long the vehicle was stationary at the drop-off location). Drop-off dwell time is measured from the time of arrival to the time of departure at the drop-off location, as recorded by AVL equipment.

- **Column I**: average travel time from when the vehicle leaves the pick-up location to the time it arrives at the drop-off location, as recorded by AVL equipment.

Trips for which data were not available (e.g., because the manifest/driver log was not provided to CUTR or the AVL information was not recorded because of equipment problems or driver error) were not included in the averages. Appendix C includes more detailed information on daily averages for each vehicle that helps to explain some of the summary data found in Table 3. The columns in Table C-1 correspond to the columns in Table 3.
### Table 3
Summary of Performance Measures

<table>
<thead>
<tr>
<th>VEHICLE #119</th>
<th>On-Time Performance</th>
<th>Dwell Time</th>
<th>On-Time Performance</th>
<th>Dwell Time</th>
<th>Ride Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(A) Pick-up Log-Sch¹ (minutes)</td>
<td>(B) Pick-up AVL-Sch² (minutes)</td>
<td>(C) Pick-up AVL³ (minutes)</td>
<td>(D) Dwell Time⁴ (minutes)</td>
<td>(E) Drop-off Log-Sch⁵ (minutes)</td>
</tr>
<tr>
<td>Vehicle Average</td>
<td>2</td>
<td>7</td>
<td>-5</td>
<td>3</td>
<td>-1</td>
</tr>
<tr>
<td>Range Low</td>
<td>-3 (early)</td>
<td>0 (on-time)</td>
<td>-7 (before)</td>
<td>0 (wait)</td>
<td>-12 (early)</td>
</tr>
<tr>
<td>High</td>
<td>13 (late)</td>
<td>17 (late)</td>
<td>-1 (before)</td>
<td>6 (wait)</td>
<td>30 (late)</td>
</tr>
<tr>
<td>VEHICLE #201</td>
<td>Vehicle Average</td>
<td>3</td>
<td>10</td>
<td>-7</td>
<td>8</td>
</tr>
<tr>
<td>Range Low</td>
<td>-4 (early)</td>
<td>3 (late)</td>
<td>-10 (before)</td>
<td>5 (wait)</td>
<td>-5 (early)</td>
</tr>
<tr>
<td>High</td>
<td>10 (late)</td>
<td>15 (late)</td>
<td>-6 (before)</td>
<td>12 (wait)</td>
<td>19 (late)</td>
</tr>
<tr>
<td>VEHICLE #303</td>
<td>Vehicle Average</td>
<td>0</td>
<td>10</td>
<td>-10</td>
<td>4</td>
</tr>
<tr>
<td>Range Low</td>
<td>0 (on time)</td>
<td>-2 (early)</td>
<td>-27 (before)</td>
<td>1 (wait)</td>
<td>-2 (early)</td>
</tr>
<tr>
<td>High</td>
<td>1 (late)</td>
<td>29 (late)</td>
<td>2 (after)</td>
<td>11 (wait)</td>
<td>3 (late)</td>
</tr>
<tr>
<td>VEHICLE #429</td>
<td>Vehicle Average</td>
<td>0</td>
<td>3</td>
<td>-3</td>
<td>6</td>
</tr>
<tr>
<td>Range Low</td>
<td>-7 (early)</td>
<td>-6 (early)</td>
<td>-8 (before)</td>
<td>1 (wait)</td>
<td>-20 (early)</td>
</tr>
<tr>
<td>High</td>
<td>8 (late)</td>
<td>12 (late)</td>
<td>0 (on time)</td>
<td>13 (wait)</td>
<td>3 (late)</td>
</tr>
<tr>
<td>OVERALL AVERAGE</td>
<td>Average All Vehicles</td>
<td>1</td>
<td>8</td>
<td>-6</td>
<td>5</td>
</tr>
<tr>
<td>Range Low</td>
<td>-7 (early)</td>
<td>-6 (early)</td>
<td>-27 (before)</td>
<td>0 (wait)</td>
<td>-20 (early)</td>
</tr>
<tr>
<td>High</td>
<td>13 (late)</td>
<td>29 (late)</td>
<td>2 (after)</td>
<td>13 (wait)</td>
<td>30 (late)</td>
</tr>
</tbody>
</table>
Table 3 Notes:

1 Column A contains the average difference between the pick-up time recorded in the driver's log (Log) and the scheduled pick-up time (Sch). A minus (-) indicates that the driver-recorded pick-up time was earlier than the scheduled pick-up time.

2 Column B contains the average differences between the time recorded by the AVL equipment (AVL) and the scheduled pick-up time (Sch). A minus (-) indicates that the AVL-recorded pick-up time was earlier than the scheduled pick-up time.

3 Column C contains the average difference between the pick-up time recorded in the driver's log (Log) and the time recorded by the AVL equipment (AVL). A minus (-) indicates that the driver-recorded pick-up time was earlier than the AVL-recorded pick-up time.

4 Column D contains the average length of the pick-up dwell (or wait) time. This number was calculated by comparing the time the vehicle arrived at a pick-up site and the time the vehicle left the pick-up site using data recorded by the AVL equipment.

5 Column E contains the average difference between the drop-off time recorded in the driver's log (Log) and the scheduled drop-off time (Sch). A minus (-) indicates that the driver-recorded drop-off time was earlier than the scheduled drop-off time.

6 Column F contains the average difference between the time recorded by the AVL equipment (AVL) and the scheduled drop-off time (Sch). A minus (-) indicates that AVL-recorded drop-off time was earlier than the scheduled drop-off time.

7 Column G contains the average difference between the drop-off time recorded in the driver's log (Log) and the real time drop-off recorded by the AVL equipment (AVL). A minus (-) indicates that the driver recorded drop-off time was earlier than the AVL-recorded drop-off time.

8 Column H contains the average length of the drop-off dwell (or wait) time. This number was calculated by comparing the time the vehicle arrived at a drop-off site and the time the vehicle left the drop-off site using data recorded by the AVL equipment.

9 Column I contains the average travel time for each trip completed, based on AVL-recorded data from the time the vehicle left the pick-up location until it arrived at the drop-off location.

Source: Data collected from completed driver manifests and AVL Detailed Event Reports. See Appendix C for detailed vehicle information.

Vehicle #119 usable data from: 9/1/95, 9/7/95, 9/19/95, 10/5/95, 10/11/95, 10/17/95, 10/23/95.
Vehicle #201 usable data from: 9/1/95, 9/7/95, 9/13/95, 9/19/95, 9/23/95, 9/29/95, 10/17/95, 10/23/95, 10/30/95.
Vehicle #303 usable data from: 9/1/95, 9/7/95, 9/19/95, 9/23/95, 9/29/95, 10/5/95, 10/17/95, 10/23/95.
Vehicle #429 usable data from: 9/1/95, 9/7/95, 9/13/95, 9/19/95, 9/25/95, 10/5/95, 10/11/95, 1/23/95, 10/30/95.
On-time Performance

On-time performance is most often measured in terms of a passenger being picked up within a specified "window." According to Zuni’s contract, a pick-up is on-time if a vehicle arrives anytime up to 15 minutes after the scheduled pick-up time. A vehicle arriving before the scheduled pick-up time is early; a pick-up after the 15-minute window is considered late and may be subject to liquidated damages. On-time performance also may be measured in terms of whether a passenger arrives at or before a scheduled appointment time.

To measure AVL’s potential contribution to measuring on-time performance, CUTR calculated three performance indicators for each trip in the sample: (1) pick-up and drop-off data recorded by drivers compared with the scheduled pick-up and drop-off times printed on the drivers’ manifests (Columns A and E, respectively), (2) AVL data recorded when drivers pressed the appropriate buttons on the status message terminal compared with the scheduled pick-up and drop-off times printed on the drivers’ manifests (Columns B and F, respectively), and (3) driver-recorded data compared to AVL-recorded data, recognizing that drivers must press the correct status message terminal button to register the AVL information (Columns C and G, respectively). The results of this analysis are described below.

- **Column A** compares the pick-up times recorded by the drivers on their manifests (Log) with scheduled pick-up times (Sch). This is usually the only information available for resolving questions of on-time performance and relies on drivers to provide accurate information. Table 3 shows the average difference between these two times is one minute, meaning that on average drivers reported arriving 1 minute later than the scheduled pick-up time (still well within the 15-minute pick-up window). The range is 7 minutes early to 13 minutes late. More detailed information is included in Appendix C.

- **Column B** compares the pick-up times recorded by the AVL equipment (AVL) with the scheduled pick-up times (Sch). Table 3 shows the average difference between these two times is 8 minutes, meaning that the AVL equipment shows on average that drivers are arriving 8 minutes later than the scheduled pick-up time (still within the 15-minute pick-up window). The range is 6 minutes early to 29 minutes late. Presumably the AVL data should be more accurate than the information recorded manually by drivers because the status message recorded when a button is pressed indicates the vehicle’s location. A driver could record information at any point and could easily “round” the time to match the required pick-up or drop-off schedule. (Keep in mind, to minimize bias, trip information was included in the sample only if the location shown by the AVL equipment matched the scheduled location for the vehicle.) More detailed information is included in Appendix C.
**Findings**

| Column C compares the pick-up times recorded by the driver on his or her manifest (Log) with the pick-up times recorded by the AVL equipment (AVL). Table 3 shows the average pick-up arrival times shown on drivers’ logs are an average of 6 minutes earlier than times recorded by the AVL equipment. The range is 24 minutes before to 52 minutes after. This difference appears to support the notion that drivers may record information manually that makes it look like their pick-up times are closer to the scheduled pick-up times than they really are, while the AVL equipment may more accurately reflect the actual pick-up times. More detailed information is included in Appendix C. |
| Column E compares the drop-off times recorded by the drivers on their manifests (Log) with scheduled drop-off times (Sch). This is usually the only information available for resolving questions of on-time performance and relies on drivers to provide accurate information. Table 3 shows the average difference between these two times is 1 minute, meaning that on average drivers reported arriving 1 minute earlier than the scheduled drop-off time. The range is 20 minutes early to 30 minutes late. This range may cause some concern, particularly for the late drop-offs that could result in missed appointments. As can be seen from Table 3, the range of drop-off times is greatest for vehicles #119 and #201; however, the averages for all of the vehicles suggest that there are no major problems with on-time performance. More detailed information is presented in Appendix C. |
| Column F compares the drop-off times recorded by the AVL equipment (AVL) with the scheduled drop-off times (Sch). Table 3 shows the average difference between these two times is 3 minutes, meaning that the AVL equipment shows on average that drivers are arriving 3 minutes later than the scheduled drop-off time. The range is 22 minutes early to 27 minutes late. This range appears to be rather broad; however, on average the AVL-recorded drop-off times are relatively close to the scheduled drop-off times. Assuming drivers pressed the status message terminal buttons correctly (and most appeared to be doing so, based on CUTR’s observations), the AVL information should be more accurate than the information recorded manually by drivers. (Keep in mind, to minimize bias, trip information was included in the sample only if the location shown by the AVL equipment matched the scheduled location for the vehicle.) More detailed information is included in Appendix C. |
| Column G compares the drop-off times recorded by the driver on his or her manifest (Log) with the drop-off times recorded by the AVL equipment (AVL). Table 3 shows the average drop-off times shown on drivers’ logs are an average of 3 minutes before the time recorded by the AVL equipment. The range is very large (24 minutes before to 52 minutes after); however, upon closer examination of the drivers’ manifests, it appears that the driver of vehicle #119 may have incorrectly recorded his drop-off time for a group trip as being an hour later than he had actually dropped-off the passengers (see Table F-1). (This was a special trip and all other trips on that day [October 17, 1995] were transferred to another vehicle. This may have skewed the data for this column.) Again, the AVL-recorded data helped to ascertain that the driver had made an error and could |
have proved valuable had there been a question of on-time performance, based on the driver's manifest. More detailed information is presented in Appendix C.

Vehicle Dwell Time

The second performance measure analyzed was vehicle dwell time. Accurate information on vehicle dwell time is seldom collected, but could be valuable information for schedulers. For example, if schedulers know a particular pick-up or drop-off location, such as a hospital, causes delays because vehicles have to wait for passengers, then the scheduler can build extra time into the schedule. Also, many paratransit systems will wait 3 to 5 minutes for a passenger who is not ready. Information related to vehicle dwell time is included in Columns D and H in Table 3.

- **Column D** shows the average vehicle dwell time when picking up passengers (i.e., the elapsed time between arriving at the pick-up location and leaving the pick-up location) was 5 minutes, with a range of 0 to 13 minutes for the sample. The dwell time was calculated using AVL-recorded information about when a vehicle arrived for a pick-up and when it departed from the pick-up location. The short dwell times suggest that most passengers are relatively mobile and ready to leave when vehicles arrive. Vehicle #201 is a lift-equipped van. Even its dwell time is relatively short (average of 8 minutes), suggesting that passengers are ready when the vehicle arrives and are quickly loaded, assuming the driver pressed the status message terminal buttons correctly. Additional information is included in Appendix C.

- **Column H** shows the average vehicle dwell time when dropping off passengers (i.e., the elapsed time between arriving at the drop-off location and leaving the drop-off location) was 4 minutes, with a range of 0 to 8 minutes for the sample. Again, this average dwell time was calculated using AVL-recorded information about when a vehicle arrived at its drop-off location and when it departed from the drop-off location. These results suggest that drivers are able to drop off passengers quickly, allowing them to move onto the next trip assignment. Additional information is included in Appendix C.

Ride Time

The third performance measure analyzed was ride time. Many systems have a restriction in place for how long a passenger may ride on board a vehicle. Liquidated damages may be assessed if passengers are kept on board beyond those limits. MDTA has a one-hour ride time limitation. Information related to ride time is included in Column I of Table 3.
### Findings

- **Column I** shows that the average ride time was 27 minutes; the range was from 15 to 50 minutes. This is valuable information for systems to use when calculating costs on a per-hour basis or when determining potential system productivity (passengers per hour). (To account for the full time required to complete a trip, the average dwell times should be added to the average ride time when computing the average elapsed time for a completed trip.) This information was based on actual time recorded using the AVL equipment, which is more accurate than information provided manually by drivers. More detailed information is included in Appendix C.

### Observations

A few observations are in order at this point. Although the AVL data analyzed for this report shows great promise for helping to accurately reflect paratransit vehicle movements, in this application drivers were required to press a button to record events (e.g., “Arrive Pick-up,” “Leave Pick-up,” “Arrive Drop-off,” “Leave Drop-off,” etc.). Therefore, an element of human error was present. Also, the time needed to complete the analysis (as described in the previous section) was considerable, making this application of AVL useful only for retrospective studies, not real-time applications.

Other AVL applications should strive to automate the AVL data collection portion to reduce the need for driver intervention. For example, by issuing magnetic swipe cards or SmartCards to passengers, the AVL equipment could automatically record all of the information relating to a specific trip when the card is swiped at the beginning and/or end of a trip. Collecting all of the data at the same time eliminates the need for complicated data matching and manipulation such as those required to complete this study and described in this section. Also, safeguards should be built in to preserve the integrity of the data when the vehicle is out of the service area or if equipment malfunctions.

Despite these shortcomings, several real-time AVL applications can be employed successfully, as described in the following section.

### Real-time AVL Applications and System Productivity

CUTR was able to collect and analyze useful AVL data from Zuni that suggests how this type of technology might be helpful for improving paratransit productivity. However, completion of this task required a considerable amount of time and data manipulation, including the use of two
BASIC computer software programs, written by CUTR research staff, and preparation of Lotus 1-2-3 spreadsheets to facilitate data analysis. The amount of time and level of effort required for this data analysis is likely beyond the capabilities of most paratransit operators working in a dynamic environment. The data are, however, useful for after-the-fact analysis for research purposes.

Thus, our findings suggest that the particular AVL technology used in this application is not, in its present state, suitable for this type of application (it should be remembered that the AVL technology used was originally installed as a theft-deterrent and not specifically designed for the use in this application). Nonetheless, Zuni staff found (and CUTR concurs) that this particular type of AVL technology does have a number of useful real-time applications to paratransit, which could contribute toward improved paratransit productivity.

**Monitor Drivers**

One of the biggest challenges faced by paratransit providers is knowing exactly where vehicles are and what drivers are doing. The AVL technology used by Zuni allows dispatchers to track and monitor drivers’ movements. New and veteran drivers may be tracked and/or monitored to ensure that schedules are adhered to and that the shortest routes are chosen. If drivers are running behind schedule, dispatchers are able to make proactive decisions about whether to reassign trips or allow the driver to remain on its existing route. These important decisions can be made in real-time before major problems occur. The ability to make real-time decisions about schedule changes may lead to improved system efficiency through reduction of liquidated damages for late and missed trips.

**Vehicle Location and Estimated Time of Arrival Requests**

Zuni receives numerous requests for estimated time of arrivals (ETAs) throughout each day (e.g., from the broker requesting information on the whereabouts of a vehicle). Instead of requiring a dispatcher to call the driver on the radio, the dispatcher can use the AVL technology to locate a vehicle’s exact location. This information allows the dispatchers to determine exactly where a vehicle is and how far it is from its ultimate destination. As a result, drivers are less distracted and Zuni dispatchers are able to provide much more accurate information to the broker or customers requesting trip information. In addition, customer service and satisfaction are
enhanced by knowing exactly where a vehicle is and being able to accurately estimate when it will arrive.

**Look-up Addresses and Identify Closest Vehicle**

Paratransit typically provides either door-to-door or curb-to-curb service. Routes may change each day and might include several hundred different addresses during the course of a week. As a result, drivers may have difficulty locating some addresses on their schedule. The Fleet Director™ software gives dispatchers the ability to plot addresses on the software’s base map. The plotted address can be viewed on-screen along with the lost driver’s vehicle. Dispatchers may then direct drivers to addresses via a two-way radio, thus reducing the number of late passenger pick-ups and drop-offs and enhancing overall system efficiency.

Paratransit trip requests for same-day service (add-ons) may be more easily accommodated with the use of AVL technology. The software includes a “closest vehicles” feature that finds the closest vehicles to a plotted address and determines each vehicle’s distance from that address. This feature assists dispatchers in making real-time decisions about same-day trip assignments. This feature also assists dispatchers when transferring trips to other drivers because a vehicle is behind schedule or delayed by traffic, vehicle accidents, or mechanical problems.

The status message terminals allow drivers to take the “closest vehicles” feature a step further. Zuni’s status message terminals include an “Available for Call” button, which can be pressed when a driver has free time in his or her schedule. Each time this status button is pressed, the AVL software updates the vehicles’ status on-screen to notify dispatch that the driver is free. Dispatchers are then able to locate the closest vehicles to a plotted address and determine if any of the drivers of those vehicles are available to take an added trip.

The “Available for Call” feature was not used to its fullest potential by Zuni dispatchers during the demonstration period. Based on observations and interviews with dispatchers, some explanations include space limitations in the dispatch area that made it difficult to easily access the computer work station and force of habit.

When the demonstration began at Zuni, the company was housed in a very small building. The dispatch area was only 200 square feet and the AVL computer work station was located behind
the dispatchers’ main work area. This configuration required dispatchers to turn completely away from the focus of their activities to view the computer screen. Introduction of the technology in such a hectic environment proved difficult. When Zuni moved to a new, larger location, the computer was placed in a more accessible place (within the direct view of dispatch), making it possible for the dispatchers to use the computer more easily.

**Document Passenger No Shows**

Paratransit efficiency and productivity are negatively affected by an abundance of passenger no shows. A “no show” occurs when a passenger does not show for a scheduled trip and does not call in advance to cancel the trip. As a result, drivers lose time traveling to the scheduled pick-up address and then must continue on their route without the passenger.

Paratransit operations that receive trip schedules from a broker may be fined for trips not completed unless passenger no shows can be documented. Zuni’s status message terminals included a button coded with a “No Show” status message. The purpose of this button was to provide Zuni management with information regarding the number of no show occurrences and documentation of the no shows for the broker. However, the information obtained from the status message terminals could not easily be submitted to the broker as documentation because no information is generated from the technology that can automatically link a passenger or trip to the status and location. For example, when a driver arrives at a scheduled pick-up and presses the appropriate status buttons on the status message terminal inside the vehicle, the status information is transmitted to Fleet Director™ along with the vehicle’s location information. No other information that would uniquely identify the trip, such as the trip number, is transmitted. Therefore, manual matching of person trips to AVL trip data would be required to document each no show occurrence for the broker.

**Monitor Safety and Security**

AVL technology can be used by paratransit operators to improve the safety and security of vehicles, drivers, and passengers. Automatic vehicle tracking makes it possible to monitor accidents and vehicle breakdowns. The status message terminals offered by this AVL vendor include a red status button that is reserved for emergency situations. When this button is pressed, the vehicle turns red on the Fleet Director™ computer screen and an alarm sounds notifying
dispatch that an emergency situation is occurring. For an additional charge, the vendor can program this status button so that police are alerted and dispatched to the vehicle’s location.

Drivers also can communicate that they are having mechanical problems or are involved in an accident with the status message terminals and/or with the two-way radio. Once dispatch has been notified of the situation, they can monitor the vehicle’s location in real-time with the AVL software.

The AVL technology used by Zuni produced vehicle location and status information that was used for an analysis of paratransit productivity and for real-time applications that may also work to improve overall system performance. Zuni’s use of the technology began as a way to deter crime. By the time this project ended, Zuni was seriously considering equipping all of its vehicles with the AVL equipment. The operation has moved to a much larger location where the AVL work station now resides in the middle of the dispatch area. Dispatchers report that they now use the system regularly to monitor vehicles and schedules. The AVL technology is beginning to be incorporated more thoroughly into the daily activities of this paratransit company.
AVL SYSTEM SELECTION AND IMPLEMENTATION

This research project afforded a great opportunity to examine the potential applications of one type of AVL technology to the paratransit field. This section of the report describes a set of questions that should be asked and answered when a paratransit agency is deciding whether to invest in an AVL system. The three major issues that were examined include: (1) determining whether there is a need for AVL, (2) selecting which AVL technology to acquire, and (3) implementing an AVL system. A checklist that corresponds to this discussion is included in Appendix D.

Determining the Need for AVL

No two paratransit systems will have precisely the same needs. Before purchasing any type of AVL technology, it is important to assess whether there is a need for such a system. This assessment should include a thorough discussion about what the goals and expectations are for the AVL system.

Develop Short- and Long-term Goals

As described in the beginning of this report, AVL technology is currently used for a number of purposes and applications, including police and fire, commercial fleets, private individuals, and transit and paratransit agencies. A paratransit agency that is interested in adding AVL technology to its vehicles should clearly state the problems or issues that AVL is expected to address. If the decision is made to proceed with the selection of an AVL system, this exercise will provide valuable information throughout the selection period regarding what will constitute an appropriate (and successful) AVL system for a particular paratransit agency.

AVL system goals should be considered for both the short- and long-term. With technological advances occurring so rapidly, what is state of the art today may be obsolete tomorrow.
Therefore, any major investment in AVL technology should consider the short- and long-term costs and benefits. In general, it is probably wise to purchase a system with as much flexibility as possible, with expansion capability for future growth and new product development.

For example, Zuni’s initial decision to purchase an AVL system was in response to a perceived need to safeguard the system’s vehicles from theft and vandalism. In fact, shortly after the system was installed, a vehicle was stolen and police were able to track the vehicle’s movements and apprehend the culprits within minutes. A secondary goal for Zuni was to provide dispatchers with computerized address look-up assistance to help drivers find unfamiliar addresses. Although the work station was not well-positioned for use by the dispatchers, it was used on occasion to lookup unknown addresses. For the purpose of this study, the existing technology was reprogrammed to enhance its utility and to allow for data collection and analysis; however, the system currently used by Zuni would have to be further modified to allow it to become truly useful in real-time application.

Other obvious goals for implementing an AVL system might include the ability to provide real-time vehicle and driver monitoring, real-time dispatching and scheduling, and ongoing driver assistance. Additional goals might include routine data collection and analysis to enhance system productivity and on-time performance. Still other goals might relate to customer service and being able to provide accurate ETAs in response to queries about a vehicle’s whereabouts. Yet another possible goal, although not explored in this research, is to automate billing through the use of SmartCard technologies in combination with AVL, as described earlier in this report.

**Involve All Personnel**

When determining goals, it would be helpful to include representatives from all aspects of the paratransit operation. Involving drivers, reservationists, customer service staff, dispatchers, schedulers, maintenance personnel, billing clerks, managers, and others will help to facilitate the exchange of ideas and may uncover some ideas and concerns that should be addressed as part of the goal-setting process.

An evaluation of AVL systems completed by the Texas Transportation Institute (Turnbull 1993) suggests establishing a core AVL system implementation team early in the process to ensure that the selected AVL system will be compatible with the desires and needs of each department.
Early and continued inclusion in analysis and decision-making also encourages buy-in and better understanding and support for all aspects of the operation.

**Be Realistic**

Finally, an important aspect to include during the goal-setting phase is to be realistic about what the AVL system can accomplish. Any technology is only as good as the humans who designed and implemented it. Therefore, expectations about the potential benefits of installing an AVL system should be realistic. AVL will not solve poor on-time performance; however, AVL may help an agency identify the cause of poor on-time service. Finally, AVL will not substitute for good supervision and management of system employees, although it will probably help them work smarter and more efficiently.

**Selecting an AVL System**

Once the goals and objectives for an AVL system have been outlined, they should be translated into desired system features and capabilities. The basic decision about what type of AVL technology to purchase depends on the desired system requirements, as described in the previous section, and the amount of funding available.

**Specify Needs**

Whether satellite- or ground-based AVL is selected, other factors need to be decided before issuing a request for proposals (RFP). Just as an agency would not issue an RFP to purchase a vehicle that is unsuitable for providing paratransit service, it also should not issue an RFP for an AVL system that is unsuitable for supporting paratransit service. Several key factors should be considered, relating back to previous section, such as desired messaging capabilities and the need to integrate with other software and hardware programs.

If data from the AVL system are intended for in-depth analyses of system performance and documentation, it is important for the chosen AVL technology to be able to produce reports in usable formats. The need for particular types of information should be identified during the exercise outlining the purpose and use of the AVL system prior to selection. A system should be
selected that will let you easily extract the information desired, preferably automatically
generating reports. Again, try to anticipate long-term data requirements.

When Zuni selected its AVL system, the primary objective was to prevent vehicle theft and to
monitor the movement of their vehicles. The system that it chose was excellent for those
purposes. However, when CUTR project staff attempted to use AVL-generated data to analyze
productivity, a significant amount of time and effort were needed to convert the data into a
format that would allow data manipulation. Unfortunately, most paratransit companies do not
have a great deal of time to devote to that level of analysis. Therefore, it is important to choose a
system that will produce reports that require few alterations to be useful for data analysis. When
deciding on reporting needs, consider who in the organization will be responsible for managing
the AVL system and analyzing data generated from the system on a regular basis.

Once the desired features and capabilities have been defined, different types of AVL
technologies, their reliability and accuracy, and the associated costs of each should be
investigated to determine which technology will be appropriate to meet those needs. When
considering different technologies and/or systems, also outline and describe the areas of the
operation where there are potential cost and time savings that may be achieved by implementing
AVL technology.

**Determine Needed Reliability & Accuracy**

As part of selecting an AVL system, the agency will want to consider the level of reliability and
accuracy required for the AVL application under consideration. Reliability has to do with
whether the system is consistently available for use. For example, is it important that the AVL
system be available at all times for billing and data collection purposes, or is it sufficient to be
available most of the time for vehicle tracking and more passive assistance? Will it be necessary
to provide for an uninterrupted power supply to keep the computer running and the system active
during a power outage? How long is the system willing to wait for the AVL vendor to fix a
broken unit or reprogram a change? How accurate are the maps and will they require a major
update to add addresses and correct errors?
Accuracy relates to how close the AVL system can plot a vehicle's location. Is it necessary to track the exact location of a vehicle within a few feet, or is it sufficient to know within 100 or 500 feet? What are the benefits and costs related to these questions of reliability and accuracy?

To ensure that a paratransit company selects technology that best meets its needs, it is important to shop around and ask a lot of questions. Do not take promotional material at face value. Ask to see the technology in action and actual reports that are available. If possible, contact companies that have implemented the system(s) that are being considered and inquire about experiences with the technology. Try to think about long-term plans for the AVL technology. For example, if there is a possibility that scheduling software may be purchased in the future, be sure that the AVL system will support integration of the scheduling software. Likewise, if a GIS system is already in place at the operation, the AVL system should also be designed to support what currently exists, rather than replacing it.

Reliability and accuracy have a price. By balancing cost against the system's stated goals, a paratransit agency will be better equipped to specify an AVL system that will serve the needs of the agency, while being fiscally responsible and cost-effective. The answers to these questions will need to be factored into the cost equation.

**Identify All Costs**

Identification of all costs associated with implementing a new technology can be tricky. As with most major capital purchases, it is no simple task to develop system specifications and to anticipate all of the costs involved in operating the system. This is especially true for new technologies such as AVL. Prior to deciding which type of system to select, agencies should get a rough idea about costs associated with various technologies (see Table 1). GPS systems are the most accurate and the most expensive; however, prices are changing rapidly and that technology is becoming far more affordable. Dead-reckoning and map matching is inexpensive, yet has poor accuracy. The best way to ballpark costs is to seek out other paratransit agencies that have recently installed AVL and to ask them about their costs.

It is essential to understand the costs associated with implementing and maintaining a new system, prior to investing in it. Significant costs to consider include the capital purchase price for additional AVL units, the cost of new computer hardware and software (including upgrades),
cost of maintenance and service agreements, cost of training personnel, additional costs for ongoing technical assistance, and the like. Be sure to negotiate a flat rate for unlimited vehicle locates so that the system is not constrained by additional incremental costs associated with vehicle locates and messaging.

**Implementing a System**

Once the AVL system has been selected, the implementation process begins. Paratransit companies introducing AVL technology into their operation should recognize that the implementation process probably will not be swift or easy. In fact, an evaluation of AVL systems in public transit completed by the Texas Transportation Institute (Turnbull 1993) suggests that full implementation, from system selection to full deployment, may take as long as two years. (One paratransit operator in Florida has been working to develop and implement an AVL system that includes billing capabilities for more than four years.)

**Implementation Schedule**

As with the introduction of all new technology, problems are bound to arise. To avoid major disruptions in daily operations, a realistic implementation schedule should be developed that reflects the amount of effort and time that will be necessary to achieve full implementation. Invariably, no matter how well the process is planned, issues will arise that prolong the implementation phase. For example, when the Zuni project was begun, CUTR assumed the data collection phase of the project would begin fairly quickly because Zuni already had AVL technology installed in a portion of its vehicle fleet. However, incomplete records, malfunctioning equipment, and reconfiguration and reinstallation of the AVL equipment resulted in an implementation process that took several months to ensure that the equipment was in working order and training was completed, prior to beginning the data collection phase.

Developing a realistic implementation schedule for the AVL system can help to minimize the impacts of unforeseen delays. The implementation schedule should include at least six months time for installation, equipment testing, and training. By anticipating potential implementation delays while developing the schedule, it becomes possible to plan ways to avoid or address delays before they create any disruptions. Detailed records should be kept documenting the equipment that is installed, vehicles included, and details about the vendor’s agreement (i.e., how
problems will be resolved, maintenance agreements, cost for locates, and other costs). Finally, the contract with the AVL vendor should stipulate that the vendor will be responsible for correcting major problems within a short period of time. If possible, a vendor that will provide plenty of technical support should be chosen, because it is impossible to anticipate all the technological questions that may arise.

**Expectations**

Once the AVL technology has been selected and implementation is underway, managers should be sure to clearly define and articulate expectations as they relate to the use of the AVL by employees. This includes thorough and ongoing discussion of the purpose for using AVL technology in the delivery of paratransit services. It is important that all staff who will be using the technology have an understanding of how the AVL technology works, as well as the role that it will play in the paratransit service and the jobs of each staff member. The study at Zuni revealed that drivers had a limited understanding of how the AVL technology worked and, consequently, many did not understand how the technology could benefit them or make their job easier. Rather, implementation of the AVL technology was perceived by some as placing additional burdens on the drivers’ jobs, with little to no added benefit for them. Additionally, several drivers expressed discomfort with a situation that they perceived to be a form of punishment—these drivers believed that dispatch was using the technology to continuously keep track of drivers.

**Human Factors**

Employees represent a major cost and critical link for paratransit operations. When AVL technology is introduced in a paratransit system, all employees will be affected. Job responsibilities, skills, and roles may be created and work loads may shift. Care should be taken to include all groups in the process of defining uses of the proposed AVL technology and selection of the actual equipment. The team approach should also be utilized throughout the implementation phase. This approach helps to ensure that all affected personnel have had an opportunity to contribute wisdom and expertise to the selection process, as well as raise any concerns they may have concerning the technology (Turnbull 1993).
Train Early and Often

It is not enough to explain how the AVL technology works, what the information will be used for, and who will be responsible for generating the necessary data. In order for the new technology to be useful, all affected parties must be properly trained to use it. This may seem obvious, but the point cannot be made often enough or strongly enough. Oftentimes, new technology enters our lives that promises to completely transform the way we do business. Personal computers (PCs) are an excellent example of technology that has transformed daily business. However, PCs are useless if the individuals expected to use them are not trained in their use. Further, without thorough and comprehensive training in the use of new technology, the technology adopted to save time and improve business may have the opposite result.

When AVL technology is added to a paratransit operation, job responsibilities and functions will undergo some amount of change. Training will be necessary to assist employees in understanding the changes taking place in their jobs and how to best adapt to those changes. Training will play a critical role in the successful implementation and utilization of AVL technology in paratransit.

This study revealed a number of issues related to training that will be relevant for other paratransit systems wishing to introduce AVL technology in their operations. The role of dispatchers is altered a great deal with the introduction of AVL technology. Many of the dispatching functions that require two-way communication between dispatch and individual drivers may be accomplished by using the newly implemented technology, thus altering normal communication activities. While this may increase the level of efficiency attained by dispatch and the amount of time available to consider situations when making important real-time scheduling decisions, it may be difficult for dispatchers to become comfortable relying on information generated from the new technology, rather than information gathered through voice communications. It is very important that training with dispatchers address any areas of concern. The training schedule developed for dispatchers should include enough time to ensure that all current and potential applications of the AVL technology are thoroughly discussed.

Training and utilization of AVL technology by dispatchers will be enhanced if the proper environment is provided for the AVL equipment. For example, a large, color computer monitor can make it easier for dispatch to use the AVL graphic for real-time dispatching and ease eye
strain caused by looking at a computer monitor for long periods. Also, the AVL computer workstation should be physically positioned so that it is accessible to dispatch and does not interrupt the natural flow of dispatch activities. With proper training, the technology can be integrated into the dispatch activities naturally and easily.

The work roles and work loads of paratransit drivers also will be affected by the implementation of AVL technology. Depending on the type of technology chosen, drivers may be asked to incorporate additional tasks into their work routine. Comprehensive, ongoing training and monitoring should be conducted with drivers to ensure that they are aware of what is expected of them and have the knowledge and skills necessary to meet those expectations.

This study was, to a large degree, dependent on consistent, accurate use of the AVL technology by Zuni’s drivers. The bulk of the drivers’ training was completed at the beginning of the study. As time went on, some drivers may have “forgotten” to use the status message terminals in their vehicles or failed to report any equipment difficulties. (A careful review of individual manifests and Detail Event Reports generated by Fleet Director™ confirmed these suspicions.) Driver training should emphasize the role that drivers will play in the successful implementation of the AVL technology. Both short- and long-term expectations should be discussed with drivers. The purpose and potential benefit of the technology should be continuously stressed so drivers and dispatchers understand the part that they will play in making the operation more successful.

A Final Note

No matter how well-prepared an agency is, something almost always goes wrong during the implementation of new technology. To protect itself, a paratransit agency should plan to run its new AVL system in parallel with current practices until it is clear that the AVL system is up and functioning well. No matter how reliable the new AVL system is expected to be, it is important to verify the data being collected are what would be expected based on past experience. In other words, if the AVL system will be used for dispatching and driver messaging, run the old system (whether it is manual or computer-based) during the initial start-up phase to ensure against any service disruptions because of lost data or missed communications. It is particularly important to run both the old system and the new AVL-based system if the new system will be used for data collection purposes related to billing. An agency would be hard-pressed to justify billing for trips if they are not properly documented.
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CONCLUSIONS

The AVL demonstration conducted at Zuni revealed strengths and weaknesses of one type of technology provided by AirTouch Teletrac. The system was found to work very well for tracking the movement of Zuni's vehicles. Although some problems were encountered with the equipment, these issues were resolved for the most part. It should be remembered that, at the time of the study, AirTouch Teletrac was in the process of selling the assets of the business to Teletrac, Inc., which may have impacted its ability to respond as quickly to technological problems or issues as would have been desired. Nonetheless, AirTouch Teletrac's staff worked closely with CUTR and Zuni throughout the project.

This research project attempted to show how automatic vehicle location technology could be applied to improve paratransit productivity. In the ideal world, a direct before-and-after comparison would have been made to determine whether there was measurable benefit to system productivity after introducing AVL technology. A more exhaustive study also could be conducted to determine whether the cost of purchasing AVL would be offset by the economic benefits.

In the real world, however, a before-and-after controlled experiment was not possible. Nonetheless, this report does point toward a potentially significant benefit for real-time applications of AVL technology. AVL can be used to monitor vehicle locations and to make accurate estimates of vehicle arrival times. The technology also can be used to monitor the progress of new drivers. The address locate function also helps dispatchers pinpoint locations and provide accurate directions to a vehicle in route to a pick up.

With respect to measuring performance and system productivity, AVL appears to have great—albeit as yet unrealized—potential. Although the AVL application used for this study was adapted to meet the research needs, new AVL technologies that directly link data collection with scheduling may benefit dispatchers and schedulers, as well as managers. Being able to accurately reflect on-time performance, dwell times, and ride times will help to correct misconceptions and will contribute toward creation of schedules that more accurately reflect real
Conclusions

Automatic billing generated via SmartCard or another technology linked with AVL capabilities is a promising application that is being implemented by several systems.

Just as personal computers have little value if the user does not understand the logic behind their use, so, too, will AVL systems have little functional value if their use and capabilities—as well as limitations—are not fully understood. The checklist provided in Appendix D raises a variety of issues and questions that should be considered prior to, during, and after installation of an AVL system. Those paratransit systems installing AVL systems in the immediate future will be true pioneers. Careful documentation of the implementation process and frequent sharing of information will help to improve implementation for systems that follow.
REFERENCES CITED


Turnbull, K. *Evaluation of Automatic Vehicle Location Systems.* Texas Transportation Institute, College Station, Texas, 1993.
APPENDIX A

DRIVER TEST
(1) At what point should the "ARRIVE PICK-UP" and "ARRIVE DROP-OFF" buttons be pressed?

The "ARRIVE PICK-UP" and "ARRIVE DROP-OFF" button should be pressed once the vehicle comes to a complete stop at the designated address.

(2) You arrive at the pick-up address and one passenger using a wheelchair boards the vehicle. What buttons should be pressed?

"ARRIVE PICK-UP" - "LEAVE PICK-UP" - "WHEELCHAIR"

(3) You arrive at the drop-off address and two passengers leave the vehicle. What buttons should be pushed?

"ARRIVE DROP-OFF" - "LEAVE DROP-OFF"

(4) What buttons would be pushed if one of the passengers in #3 were using a wheelchair?

"ARRIVE DROP-OFF" - "LEAVE DROP-OFF" - "WHEELCHAIR"

(5) What must occur after the you press each button and before the you can press the next button?

The driver must wait for the acknowledgment light to illuminate before pressing the next button.

(6) What should you do if the red "Call" light is lit on the Teletrac console?

You should call dispatch.

(7) You arrive at a pick-up address and the person scheduled to be picked-up refuses the trip. What buttons should be pushed?

"ARRIVE PICK-UP" - "LEAVE PICK-UP" - "REFUSED TRIP"

(8) When should the "AVAILABLE FOR CALL" button be pressed?

The "AVAILABLE FOR CALL" button should be pressed any time that you have a gap of an hour or more in your route and can take additional work.
(9) When should the "CANCEL ENTRY" button be pushed?

The "CANCEL ENTRY" button should be pressed if you press a button by mistake. This button only cancels the last button pushed.

(10a) You arrive at the pick-up address printed on your manifest. The passenger is nowhere in sight and you suspect that the address is wrong. What should you do?

"ARRIVE PICK-UP" - "INFO HELP" - Call dispatch

(10b) What if dispatch determines that the address listed on the manifest is wrong?

"LEAVE PICK-UP" - "WRONG ADDRESS"

(11) You arrive at the designated pick-up address expecting to pick-up four people. Three people get on the vehicle and one person is a "No Show". Two of the passengers are using wheelchairs. What buttons should you push for this pick-up?

"ARRIVE PICK-UP" - "LEAVE PICK-UP" - "WHEELCHAIR" - "WHEELCHAIR" - "NO SHOW"

(12) You arrive at the pick-up address. Your manifest indicates that two people should be picked-up, but both people turn out to be "No Shows". What buttons should be pressed?

"ARRIVE PICK-UP" - "LEAVE PICK-UP" - "NO SHOW" - "NO SHOW"
APPENDIX B

SAMPLE DETAILED EVENT REPORT
How to Read a Detailed Event Report

Each line of the Detailed Event Report represents a vehicle location event. A vehicle locate is triggered either by the driver pressing a status button message (e.g., WC for wheelchair) or the automatic location polling done every two minutes.

- The “label” column refers to the vehicle number (in this case Vehicle #201).
- The “status” column refers to the vehicle’s status as a result of pressing a status message button or the automatic locate (e.g., in the first line WC appears indicating the last status received was a wheelchair boarding).
- The “heading” column refers to the speed and direction of the vehicle (e.g., 10W indicates the vehicle was moving west at 10 mph).
- The “time” and “date” columns refer to the time and date the status message was registered (e.g., 5:24:18 a.m., September 19, 1995).
- The “location event” heading refers to the cross-street location of the vehicle at the time the status message button was pressed (e.g., SW 40th Street between SW 98th Avenue and SW 97th Avenue, which was Zuni’s base location at the time).
<table>
<thead>
<tr>
<th>Label</th>
<th>Status Heading Time</th>
<th>Date</th>
<th>Location/Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>201</td>
<td>WC 0 05:24:18am 09/19/95</td>
<td>SW 40TH ST btw SW 98TH AV &amp; SW 97TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 0 05:26:03am 09/19/95</td>
<td>SW 40TH ST btw SW 98TH AV &amp; SW 97TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 0 05:28:04am 09/19/95</td>
<td>SW 40TH ST btw SW 98TH AV &amp; SW 97TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 0 05:30:02am 09/19/95</td>
<td>SW 40TH ST btw SW 98TH AV &amp; SW 97TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 0 05:32:04am 09/19/95</td>
<td>SW 40TH ST btw SW 98TH AV &amp; SW 97TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 0 05:34:01am 09/19/95</td>
<td>SW 40TH ST btw SW 98TH AV &amp; SW 97TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 0 05:36:03am 09/19/95</td>
<td>SW 40TH ST btw SW 98TH AV &amp; SW 97TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 10W 05:38:00am 09/19/95</td>
<td>SW 40TH ST btw SW 107TH AV &amp; SW 104TH CT.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 19W 05:40:02am 09/19/95</td>
<td>SW 40TH ST btw SW 113TH AV &amp; SW 112TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 27SW 05:42:00am 09/19/95</td>
<td>DADE EXWY btw SW 40TH ST &amp; SW 56TH ST.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 66S 05:44:03am 09/19/95</td>
<td>DADE EXWY btw SW 88TH ST &amp; SUNSET DR.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 65S 05:46:01am 09/19/95</td>
<td>DADE EXWY at SW 120TH ST.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 60S 05:48:04am 09/19/95</td>
<td>DADE EXWY btw SW 117TH AV &amp; SW 152ND ST.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 64S 05:50:03am 09/19/95</td>
<td>DADE EXWY btw SW 184TH ST &amp; SW 186TH ST.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 64S 05:52:03am 09/19/95</td>
<td>DADE EXWY btw SW 216TH ST &amp; SW 211TH ST.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 50S 05:54:00am 09/19/95</td>
<td>DADE EXWY btw SW 248TH ST &amp; OLD CUTLER RD.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 58SW 05:56:04am 09/19/95</td>
<td>256TH ST at 124TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 64SW 05:58:03am 09/19/95</td>
<td>DADE EXWY btw SW 288TH ST &amp; SW 137TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 64SW 06:00:12am 09/19/95</td>
<td>DADE EXWY btw SW 312TH ST &amp; SW 288TH ST.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 27W 06:02:01am 09/19/95</td>
<td>SW 312TH ST btw SW 162ND AV &amp; SW 308TH ST.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 35W 06:04:13am 09/19/95</td>
<td>SW 312TH ST btw NE 5TH AV &amp; NE 4TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 06:06:03am 09/19/95</td>
<td>Vehicle off or out of service area.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>WC 06:08:04am 09/19/95</td>
<td>MOWRY DR btw NW 10TH AV &amp; SW 9TH AV.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>AR 06:09:13am 09/19/95</td>
<td>RCV [11] - ARRIVE PICK-UP</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>AR 06:09:13am 09/19/95</td>
<td>Driver Status Changed.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>AR 06:09:13am 09/19/95</td>
<td>RCV [12] - LEAVE PICK-UP</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>AR 06:09:13am 09/19/95</td>
<td>Driver Status Changed.</td>
<td></td>
</tr>
<tr>
<td>201</td>
<td>AR 06:09:13am 09/19/95</td>
<td>Driver Status Changed.</td>
<td></td>
</tr>
<tr>
<td>Date/Time</td>
<td>Driver Status</td>
<td>Location/Direction</td>
<td>Comments</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
<td>--------------------</td>
<td>----------</td>
</tr>
<tr>
<td>06/30/95</td>
<td>06:30:07am</td>
<td>WC 27NE</td>
<td></td>
</tr>
<tr>
<td>06/30/95</td>
<td>06:32:01am</td>
<td>WC 56NE</td>
<td></td>
</tr>
<tr>
<td>06/30/95</td>
<td>06:34:01am</td>
<td>WC 63NE</td>
<td></td>
</tr>
<tr>
<td>06/30/95</td>
<td>06:36:01am</td>
<td>WC 61NE</td>
<td></td>
</tr>
<tr>
<td>06/30/95</td>
<td>06:38:10am</td>
<td>WC 0</td>
<td></td>
</tr>
<tr>
<td>06/40/95</td>
<td>06:40:02am</td>
<td>WC 64NE</td>
<td></td>
</tr>
<tr>
<td>06/42:01am</td>
<td>06/44:26am</td>
<td>WC 35NE</td>
<td></td>
</tr>
<tr>
<td>06/46:12am</td>
<td>06/46:12am</td>
<td>WC 22N</td>
<td></td>
</tr>
<tr>
<td>06/47:14am</td>
<td>06/47:14am</td>
<td>AR</td>
<td></td>
</tr>
<tr>
<td>06/47:20am</td>
<td>06/47:20am</td>
<td>AR</td>
<td></td>
</tr>
<tr>
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APPENDIX C

DETAILED PERFORMANCE MEASURES
Table C-1
Detailed Performance Measures by Vehicle

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<tr>
<th>Date</th>
<th>(A) Pick-up Log-Sch(^1) (minutes)</th>
<th>(B) Pick-up AVL-Sch(^2) (minutes)</th>
<th>(C) Pick-up Dwell Time(^4) (minutes)</th>
<th>(D) Drop-off Log-Sch(^5) (minutes)</th>
<th>(E) Drop-off AVL-Sch(^6) (minutes)</th>
<th>(F) Drop-off Log-AVL(^7) (minutes)</th>
<th>(H) Drop-off Dwell Time(^4) (minutes)</th>
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Table C-1  
Detailed Performance Measures by Vehicle

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<th>(C) Pick-up Log-AVL² (minutes)</th>
<th>(D) Dwell Time ¹ (minutes)</th>
<th>(E) Drop-off Log-Sch⁵ (minutes)</th>
<th>(F) Drop-off AVL-Sch⁷ (minutes)</th>
<th>(G) Drop-off Log-AVL⁶ (minutes)</th>
<th>(H) Travel Time⁸ (minutes)</th>
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³Sch = Schedule ⁴AVL = Automatic Vehicle Location ⁵Log-AVL = Log-AVL ⁶AVL = AVL ⁷Sch = Schedule ⁸Travel Time
## Table C-1
**Detailed Performance Measures by Vehicle**

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<th>© Pick-up Log-AVL(^5) (minutes)</th>
<th>(D) Pick-up Dwell Time(^4) (minutes)</th>
<th>(E) Drop-off Log-Sch(^2) (minutes)</th>
<th>(H) Drop-off AVL-Sch(^7) (minutes)</th>
<th>(G) Drop-off Log-AVL(^6) (minutes)</th>
<th>(H) Drop-off Dwell Time(^8) (minutes)</th>
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<td>1 Column A contains the average daily difference between the pick-up time recorded in the driver's log (Log) and the scheduled pick-up time (Sch). A minus (-) indicates that the driver-recorded pick-up time was earlier than the scheduled pick-up time.</td>
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<td>3 Column C contains the average daily difference between the pick-up time recorded in the driver's log (Log) and the time recorded by the AVL equipment (AVL). A minus (-) indicates that the driver-recorded pick-up time was earlier than the AVL-recorded pick-up time.</td>
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<td>4 Column D contains the daily average length of the pick-up dwell (or wait) time. This number was calculated by comparing the time the vehicle arrived at a pick-up site and the time the vehicle left the pick-up site using data recorded by the AVL equipment.</td>
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<td>5 Column E contains the average daily difference between the drop-off time recorded in the driver's log (Log) and the scheduled drop-off time (Sch). A minus (-) indicates that the driver-recorded drop-off time was earlier than the scheduled drop-off time.</td>
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<td>6 Column F contains the average daily difference between the time recorded by the AVL equipment (AVL) and the scheduled drop-off time (Sch). A minus (-) indicates that AVL-recorded drop-off time was earlier than the scheduled drop-off time.</td>
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<td>7 Column G contains the average daily difference between the drop-off time recorded in the driver's log (Log) and the real time drop-off recorded by the AVL equipment (AVL). A minus (-) indicates that the driver recorded drop-off time was earlier than the AVL-recorded drop-off time.</td>
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<td>8 Column H contains the daily average length of the drop-off dwell (or wait) time. This number was calculated by comparing the time the vehicle arrived at a drop-off site and the time the vehicle left the drop-off site using data recorded by the AVL equipment.</td>
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<td>9 Column I contains daily the average travel time for each trip completed, based on AVL-recorded data from the time the vehicle left the pick-up location until it arrived at the drop-off location.</td>
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APPENDIX D

AVL SYSTEM SELECTION CHECKLIST
AVL SYSTEM SELECTION CHECKLIST

I. Determining the Need for AVL

➢ Establish long- and short-term goals
➢ Involve all personnel
➢ Be realistic about expectations

☐ system safety & security
☐ vehicle location & tracking
☐ monitoring drivers’ whereabouts
☐ training new drivers
☐ communications & messaging capabilities
☐ address look-up
☐ data collection
☐ report generation
☐ billing
☐ customer service (on-time, ETAs)
☐ real-time dispatching
☐ real-time scheduling
☐ flexibility for future expansion
☐ include reservationists, dispatchers, schedulers, drivers, billing clerks, reservationists, maintenance, managers in goal-setting
☐ establish implementation team early

II. Selecting a System

➢ Be specific about needs
➢ Establish a tolerance level for reliability and accuracy
➢ Identify all costs

☐ required features
☐ desired features
☐ technology options
☐ automatic reporting capability
☐ ad hoc reporting capability
☐ visit other systems with functioning AVL systems
☐ future expansion/adaptation capabilities
☐ link with other technologies (e.g., SmartCards)
☐ required system reliability
☐ required level of accuracy
- capital cost to purchase AVL equipment
- associated computer hardware & software requirements
- cost for additional units
- cost to convert & interface with existing hardware & software
- cost to generate reports
- cost to customize reports
- flat rate for unlimited vehicle locates
- training, re-training & technical assistance costs

III. Implementing a System

- Develop an implementation schedule
- Clarify system expectations
- Consider human factors
- Begin training early

- anticipate potential delays
- allow enough time for implementation
- plan ahead to avoid service disruptions
- keep accurate installation records
- negotiate extended technical assistance from the vendor during start-up
- review expectations and system goals with all employees
- be sensitive to and understanding of employees’ concerns
- maintain team approach
- refine/redefine job responsibilities prior to system initiation
- clarify roles and responsibilities
- train and retrain all employees, as needed
- make contingency plans and run a parallel (back-up) system initially